Watershed Work Plan
Kahaluu Watershed

CITY and COUNTY of HONOLULU, HAWAII

JULY, 1969

Prepared under the authority of the Watershed Protection & Flood Prevention Act (Public law 566, 83rd. Congress, 68 Stat. 666) as amended.

USDA-SCS-PORTLAND, OREG. 1969

Helen Hopkins
47-130 Kaboho Pl.
Kaneohe 96744

WATERSHED WORK PLAN

Kahaluu Watershed

City and County of Honolulu, Hawaii

ADDENDUM

With costs amortized at 4-7/8% over a 100-year period, the comparison of benefits and costs will be as follows:

> "Total annual primary benefits will be $503,817. The annual cost of installing the measures from which these benefits will accrue will be $439,227. The overall benefit cost ratio is 1.2 to 1."

Benefits for the construction unit are in excess of costs amortized at 4-7/8% over a 100-year period.

September 1969

WATERSHED WORK PLAN AGREEMENT

KAHALUU WATERSHED

JULY 1969

WATERSHED WORK PLAN AGREEMENT

between the

Windward Oahu Soil and Water Conservation District

and the

City and County of Honolulu

(hereinafter referred to as the Sponsoring Local Organizations)

State of Hawaii

and the

Soil Conservation Service
United States Department of Agriculture
(hereinafter referred to as the Service)

Whereas, application has heretofore been made to the Secretary of Agriculture by the Sponsoring Local Organizations for assistance in preparing a plan for works of improvement for the Kahaluu Watershed, State of Hawaii, under the authority of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress; 68 Stat. 666), as amended; and

Whereas, the responsibility for administration of the Watershed Protection and Flood Prevention Act, as amended, has been assigned by the Secretary of Agriculture to the Service; and

Whereas, there has been developed through the cooperative efforts of the Sponsoring Local Organizations and the Service a mutually satisfactory plan for works of improvement for the Kahaluu Watershed, State of Hawaii, hereinafter referred to as the watershed work plan, which plan is annexed to and made a part of this agreement;

Now, therefore, in view of the foregoing considerations, the Sponsoring Local Organizations and the Secretary of Agriculture, through the Service, hereby agree on the watershed work plan, and further agree that the works of improvement as set forth in said plan can be installed in about five years.

It is mutually agreed that in installing and operating and maintaining the works of improvement substantially in accordance with the terms, conditions, and stipulations provided for in the watershed work plan:

1. Except as hereinafter provided, the Sponsoring Local Organizations will acquire without cost to the Federal Government such land rights as will be needed in connection with the works of improvement. (Estimated Cost $1,961,180). The percentages of this cost to be borne by the Sponsoring Local Organizations and the Service are as follows:

Works of Improvement	Sponsoring Local Organizations (percent)	Service (percent)	Estimated Land Rights Cost (dollars)
Multiple-purpose Channel KA-1 and Recreational Facilities:			
Payment to landowners for about 50 acres	80.0	20.0	954,020
Cost of relocation of improvements:* Two houses	50.0	50.0	10,000
All other improvements	100.0	0.0	670,660
Legal fees, survey costs, flowage easements, and other	100.0	0.0	9,640
All other Structural Measures	100.0	0.0	316,860

*Including necessary engineering services and construction costs.

The Sponsoring Local Organizations agree that all land acquired or improved with P. L. 566 financial or credit assistance will not be sold or otherwise disposed of for the evaluated life of the project except to a public agency which will continue to maintain and operate the development in accordance with the Operation and Maintenance Agreement.

2. The Sponsoring Local Organizations will acquire or provide assurance that landowners or water users have acquired such water rights pursuant to State law as may be needed in the installation and operation of the works of improvement.

3. The percentages of construction costs of structural measures to be paid by the Sponsoring Local Organizations and by the Service are as follows:

Works of Improvement	Sponsoring Local Organizations (percent)	Service (percent)	Estimated Construction Cost (dollars)
Multiple-purpose Channel System	3.3	96.7	913,580
Recreational Facilities	50.0	50.0	276,660
Stream Channel Improvements, Debris and SAF Basins	0.0	100.0	2,718,860

4. The percentages of the engineering costs to be borne by the Sponsoring Local Organizations and the Service are as follows:

Works of Improvement	Sponsoring Local Organizations (percent)	Service (percent)	Estimated Engineering Costs (dollars)
Multiple-purpose Channel System	0.0	100.0	106,050
Recreational Facilities	100.0	0.0	27,670
Stream Channel Improvements, Debris and SAF Basins	0.0	100.0	326,350

5. The Sponsoring Local Organizations and the Service will each bear their cost of project administration estimated at $236,350 and $374,090, respectively.

6. The Sponsoring Local Organizations will obtain agreements from owners of not less than 50 percent of the land above each reservoir and floodwater retarding structure that they will carry out conservation farm or ranch plans on their land.

7. The Sponsoring Local Organizations will provide assistance to landowners and operators to assure the installation of the land treatment measures shown in the watershed work plan.

8. The Sponsoring Local Organizations will encourage landowners and operators to operate and maintain the land treatment measures for the protection and improvement of the watershed.

9. The Sponsoring Local Organizations will be responsible for the operation and maintenance of the structural works of improvement by actually performing the work or arranging for such work in accordance with agreements to be entered into prior to issuing invitations to bid for construction work.

10. The costs shown in this agreement represent preliminary estimates. In finally determining the costs to be borne by the parties hereto, the actual costs incurred in the installation of works of improvement will be used.

11. This agreement is not a fund obligating document. Financial and other assistance to be furnished by the Service in carrying out the watershed work plan is contingent on the appropriation of funds for this purpose.

    A separate agreement will be entered into between the Service and the Sponsoring Local Organizations before either party initiates work involving funds of the other party. Such agreement will set forth in detail the financial and working arrangements and other conditions that are applicable to the specific works of improvement.

12. The watershed work plan may be amended or revised, and this agreement may be modified or terminated, only by mutual agreement of the parties hereto.

13. No member of or delegate to Congress, or resident commissioner, shall be admitted to any share or part of this agreement, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this agreement if made with a corporation for its general benefit.

14. The program conducted will be in compliance with all requirements respecting nondiscrimination as contained in the Civil Rights Act of 1964 and the regulations of the Secretary of Agriculture (7 C.F.R. 15.1-15.12), which provide that no person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any activity receiving Federal financial assistance.

WINDWARD OAHU SOIL AND WATER CONSERVATION DISTRICT

By Howard P. Cowan

Title Chairman

Date June 23, 1969

The signing of this agreement was authorized by a resolution of the governing body of the Windward Oahu Soil and Water Conservation District, adopted at a meeting held on June 23, 1969.

Ralph K. Ajifu
(Secretary)

Date June 23, 1969

CITY AND COUNTY OF HONOLULU

By Frank F. Fasi

Title Mayor

Date July 15, 1969

The signing of this agreement was authorized by a resolution of the governing body of the City & County of Honolulu, adopted at a meeting held on July 1, 1969.

Eileen K. Lota
(City Clerk)

Date July 16, 1969

Soil Conservation Service
United States Department of Agriculture

By _____
(Administrator)

Date _____

WATERSHED WORK PLAN

KAHALUU WATERSHED

CITY AND COUNTY OF HONOLULU, HAWAII

Prepared under the Authority of the Watershed Protection and Flood Prevention Act. (Public Law 566, 83rd Congress; 68 Stat. 666), as Amended.

Prepared by:

Windward Oahu Soil
and
Water Conservation District

and the

City and County of Honolulu

With assistance by:

U. S. Department of Agriculture
Soil Conservation Service

and the

U. S. Department of Agriculture
Forest Service

July 1969

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WATERSHED WORK PLAN

KAHALUU WATERSHED

City and County of Honolulu, Hawaii

SUMMARY OF PLAN

The Kahaluu watershed is located on the windward northeast side of the island of Oahu, Hawaii. The watershed covers an area of 4,420 acres. Present land use pattern includes 52 percent in forest land, 20 percent in grassland, 23 percent in agricultural land, and 5 percent in business-residential use.

The watershed work plan was prepared by the Windward Oahu Soil and Water Conservation District and the City and County of Honolulu, the sponsoring local organizations. Technical assistance was provided by the Soil Conservation Service and the Forest Service of the U. S. Department of Agriculture.

The primary objectives of the project are to provide effective land treatment on watershed lands and to prevent floodwater and sediment damage in the flood plain. A secondary objective is to provide a water-based recreational development for Kahaluu and nearby communities. The works of improvement for protection and development of the watershed will be installed during a five-year period. The total installation cost is estimated to be $7,896,460. The Public Law 566 share is $4,811,500, while the share borne by other funds is $3,084,960. In addition, other funds will bear the entire cost of operation, maintenance, and replacement of the structural works and recreational-use facilities at an estimated annual cost of $61,900.

Land Treatment Measures

The land treatment measures will include needed soil and water conservation practices to reduce runoff and sediment production, maintain favorable soil conditions and productivity, and restore eroded lands.

Emphasis will be placed on accelerating installation of land treatment measures on man-made erosion scars to permit maximum efficiency in the operation of the structural measures and to remove unsightly blemishes on the countryside. Reforestation practices on open forest or brush covered lands zoned for conservation use will enhance the scenic values and wildlife resources of these lands.

The total cost of installing these measures is estimated at $955,670. This will include $68,610 of Federal (PL-566) funds for providing accelerated technical assistance to the land owners and operators.

Structural Measures

The structural measures in the plan include 14,010 feet of concrete-lined channels, two debris basins, two energy-dissipating structures, and a 28-acre multi-purpose lagoon encircled by a 22-acre park with recreational facilities.

The total cost for installation of all structural measures is estimated at $6,940,790. The Federal (PL-566) share will be $4,742,890, and the share from other funds will be $2,197,900.

Comparison of Benefits and Costs

The estimated average annual benefits attributable to structural measures will be $516,390. These include $331,850 from flood prevention, $144,810 from recreation and $39,730 from secondary benefits.

The estimated average annual cost of these measures will be $386,450.

The ratio of overall benefits to costs is 1.3 to 1.0.

Cost Sharing for Structural Measures

All costs for structural works of improvement are allocated to the purposes served. Costs will be shared as follows:

Flood Prevention: PL-566 funds will bear all costs for construction and engineering services. Other funds will bear all costs of land rights.

Recreation: PL-566 funds will bear 50 percent of the construction and land rights costs and 100 percent of the engineering services other than for basic facilities and land rights. Other funds will pay for the remaining construction and land rights costs and for all engineering services for basic facilities and land rights.

Project Installation

The installation of land treatment measures will be the responsibility of individual land owners or operators. Technical assistance will be provided by the Soil Conservation Service through cooperative agreements with the Windward Oahu Soil and Water Conservation District and the State Division of Forestry. Cost of eligible agricultural measures may be shared through the Agricultural Conservation Program and other funds.

The installation of structural measures will be the responsibility of the City and County of Honolulu with technical assistance from the Soil Conservation Service.

Operation and Maintenance

Land treatment measures will be maintained by owners and operators under agreement with the Windward Oahu Soil and Water Conservation District.

The structural measures and the recreational-use facilities will be operated and maintained by the City and County of Honolulu.

DESCRIPTION OF WATERSHED

Physical Data

Location

The Hawaiian Archipelago extends more than 1,600 miles across the Pacific Ocean on a northwest-southeast axis. Oahu is one of the eight major islands that lie at the southeastern end of the chain. Its principal urban center, the city of Honolulu, is the focal point of political and economic activities in the State. The Kahaluu watershed, on the northeast side of Oahu, is separated from Honolulu by the Koolau mountain range. The watershed is in the Windward Oahu Soil and Water Conservation District. (See Project Map.)

The watershed, comprising 4,420 acres in the County of Honolulu, is situated near 21°26' north latitude and 157°52' west longitude. The town of Kahaluu, set along the shores of Kaneohe Bay, is the center of activities in the watershed. It is five miles northwest of the Kaneohe-Kailua-Lanikai urban complex and 11 miles northeast of Honolulu.

The upper and lateral boundaries of the watershed are formed by the nearly vertical cliffs of the Koolau mountain range. At the base of the cliffs, the land abruptly flattens into the flood plain.

Three amphitheatre-shaped valleys, formed by the Ahuimanu, Kahaluu, and Waihee streams, comprise the upper watershed. These streams join in the lower flood plain to form the main Kahaluu Stream which outlets into the Bay.

Climate

The Hawaiian Islands, located at the northern margin of the Tropics, enjoy a mild, subtropical climate. Arctic waters which drift into the region from the Bering Sea cool the sea breezes which sweep over the land. This brings about milder temperatures than would be expected at these latitudes. The mean temperature in Honolulu is 75.9°F. with an average minimum of 69.8°F. and an average maximum of 81.9°F.

The Kahaluu watershed is exposed to the prevailing northeasterly trade winds. The Koolau mountains, oriented perpendicular to the trade winds, deflect the air upward. Cooling as it rises, condensation and rainfall often occur under these conditions. This results in a high average yearly rainfall of about 180 inches in the upper watershed. By contrast, the average annual precipitation in the coastal areas only 2-1/2 miles away is about 70 inches.

The Hawaiian Islands are exposed to three classes of weather disturbances which produce torrential rains. These are the cold-front storms, the cyclonic "kona" storms, and the rarer tropical storms or hurricanes. The major storm systems usually occur during the months of October through May.

In addition to the major storms, the windward sections of the island of Oahu are subjected to intense local storms which are more pronounced during the winter and spring months. These local storms are of relatively short duration but often include bursts of extremely high rainfall intensities.

The growing season is twelve months long with only a slight reduction in the growth rate during the winter months. This is due to the relatively uniform temperatures and day-lengths experienced throughout the year.

Geology

The mountains of the Kahaluu watershed are of volcanic origin. The lavas of the Koolau volcano were extruded in Tertiary time from rift zones. The flows during this period have a thickness of about 3,000 feet consisting of thin layers of pahoehoe and aa interbedded with small amounts of ash. Practically all of the lavas were erupted from narrow fissures with the absence of large lava fountains.

During the Pleistocene period, large parts of the Koolau mountains were eroded by fluvial and marine action. In the Kahaluu watershed, the streams flowed in deep amphitheater-headed valleys which were framed by steep cliffs. The palis or cliffs were formed by two processes. The valleys were first eroded out by the early-formed streams. The valleys and the stream

divides were then buried by alluvia which accompanied a deep submergence of the island. After the land again emerged, the cliffs were cut by fluvial and marine erosion into essentially their present form. In more recent times, the island went through a series of submergences and emergences. Evidence indicates that at one time the valleys were submerged to a depth of about 1,200 feet. During the final emergence of the island, the sea remained for a short period 5 feet above the shore line and then established itself at the present level.

Cover Conditions

About 52 percent of the watershed is in forest cover. This includes lands within the Waiahole Forest Reserve and lands outside the Reserve but in forest cover. The major species of plants in the forest area include the following trees and brushes: Koa (Acacia koa), Java plum (Eugenia cumini), kukui or candlenut tree (Aleurites moloccana), hala (Pandanus odoratissimus), Christmas berry (Schinus terebinthifolius), mango (Mangifera indica), monkey-pod (Samanea saman), koa haole (leucaena glauca), ohia lehua (Metrosideros collina), lantana (Lantana camara), guava (Psidium guajava), hau (Hibiscus tiliaceus), false staghorn fern (Dicranopteris linearis), and Japanese tea (Cassia leschenaultiana). The grasses include: Paragrass (Panicum brachiaris), bermudagrass (Cynodon dactylon), hilograss (Paspalum conjugatum), and honohono (Commelina diffusa). In addition, forage plants have been introduced, such as kikuyugrass (Pennisetum clandestinum), pangolagrass (Digitaria decumbens) and intortum (Desmodium intortum).

Soils

The predominant soils of the watershed were developed under a cover of grass and tropical flora in a subtropical climate. The soils in the more moist, higher elevation were formed under a forest cover.

The soil map (Fig. 1) shows the general soils of the watershed. These are described as follows:

Hanalei - Pearl Harbor General Soil Area: This general soil area consists of very poorly drained soils developed from recent alluvium. It occupies the gently sloping bottomlands adjacent to the ocean and along the

streams. The soil occurs at elevations ranging from sea level to about 600 feet in the upper valleys. Annual rainfall ranges from 70 to 100 inches. This general soil area comprises about 14 percent of the watershed. Most of the area is in grass with some acreage in taro and banana.

In this general soil area, the Hanalei soils make up about 65 percent of the area, Pearl Harbor about 10 percent, and Tropaquepts about 25 percent.

Hanalei soils have a very dark grayish-brown, silty clay surface layer. The subsoil is dark grayish brown and consists of stratified layers of silty clay and silty clay loam. The water table fluctuates during rainy periods.

Pearl Harbor soils have a very dark-gray clay surface layer and subsoil. It is underlain with peat or muck and has a permanent water table at depths of 20 to 50 inches.

Tropaquepts are soils that developed their poorly drained conditions through cultivation of water crops. They have a dark-gray, mucky, silt loam surface layer and a gray, yellow, and brown silty clay subsoil.

Waikane - Lolekaa General Soil Area: This general soil area consists of well-drained soils developed from old alluvium and colluvium of basic igneous rock. It occupies gently sloping to moderately steep alluvial fans and terraces and steep colluvial slopes. Elevations range from 100 feet to 800 feet with annual rainfall from 80 to 150 inches. This general soil area makes up about 50 percent of the watershed. Where slopes are gently sloping to moderately steep, the soils are used for truck crops, banana, and homesites. The steeper soils support vegetation which helps to protect the watershed.

Waikane soils make up about 65 percent and Lolekaa soils about 35 percent of the general soil area.

Waikane soils have a dark-brown, firm, silty clay surface layer and a dark reddish-brown, firm, silty clay subsoil. The substratum is soft, weathered, gravelly alluvium and colluvium.

Lolekaa soils have a dark-brown, friable, silty clay surface layer and upper subsoil. The lower subsoil is dark yellowish-brown, friable loam. The substratum is soft, weathered, gravelly alluvium and colluvium.

Alaeloa General Soil Area: The Alaeloa series is the only soil in this general soil area. It is well drained and is developed from basic igneous rock. It occupies steep residual upland slopes. Elevations range from near sea level to 500 feet. Annual rainfall is about 75 inches. This general soil area comprises about 8 percent of the watershed.

Alaeloa soils have a dark reddish-brown, firm, silty clay surface layer and a dark-red, friable, silty clay subsoil. Soft, weathered rock occurs at depths ranging from 3 to more than 5 feet. Included are narrow steep ridgetops where the soils are shallow.

Rock Outcrop General Soil Area: Rock outcrop is the only unit in this general soil area. It occupies the precipitous cliffs of the Koolau Range. Elevations range from 800 to 2,700 feet. Annual rainfall is 150 to 180 inches. This general soil area comprises about 28 percent of the watershed.

Rock outcrop consists of more than 90 percent outcrop of solid rock. The remaining areas have a layer of soil less than 6 inches thick.

Marinelife

Kaneohe Bay, with an area of 14 square miles, is well protected by a reef barrier with only two man-made channels to sea. The bay is a haven for small fish and crabs. The anchovy or nehu, Anchoviella purpureus, is indispensable as live bait for the skipjack tuna industry. The nehu is also an important forage species for the more desirable game and food fishes. Mullet, Mugil cephalus, is also found in the bay. In Hawaii, it

is one of the more important food fishes and has been reared in ponds for hundreds of years. Tilapia, Tilapia macrocephala, which was introduced to Hawaii as a bait fish, is being caught more and more for recreational and eating purposes.

Various species of crabs are found in the bay and are netted by children and adults for fun and food. The limited clam season draws thousands of Honoluluans to dig for the recently introduced Manila clam, Venerupis philippinarum.

Economic Data

Land Use Pattern

Present land use pattern in the watershed is distributed as follows: 52 percent in forest land, 20 percent in grassland, 23 percent in agricultural land, and 5 percent in business-residential use.(See Figure 2.) Most of the land is privately owned, except for the Forest Reserve, which is owned by the City and County of Honolulu.

Historically, the economic base of the watershed has been agriculturally oriented. Agricultural uses continue to dominate the present land pattern; however, the rapid urbanization of the outskirts of Honolulu in recent years has now reached the fringes of the watershed. The fast, modern highways being developed in the City and County of Honolulu have accelerated the "suburbanization" of its surrounding rural communities by placing them within easy commuting distance. Kahaluu residents are now only 20 minutes away from downtown Honolulu. They are now also only ten minutes from the Kaneohe-Kailua-Lanikai complex, the second largest urban center in the State.

The State Land Use Law, passed by the First State Legislature in 1961, provided for the zoning of all lands by uses. It empowered the state to classify and regulate uses to urban, rural, agricultural, and conservation purposes. The main objectives of the act were to protect prime agricultural land from needless residential development and to induce orderly urban development. In the Kahaluu watershed, urban-zoned lands are still relatively undeveloped, with most still in agricultural use. (See Figure 3.)

Population and Population Characteristics

During the period 1950 to 1960, the Kaneohe-Kailua-Lanikai population growth of 185 percent was greater than any other comparable area of the state. The population in the nearby Kahaluu watershed, however, remained relatively static, numbering 3,340 in 1960. After this period, the watershed population began to increase, numbering 5,480 in 1966.

Entering the Town of Kahaluu in early spring SCS PHOTO 4-1084-13

Factors contributing to the sharp upward trend of the Windward Oahu population are:

1. A rapidly rising island population which is beginning to "spill over" into the windward section of the island from crowded Honolulu proper.

2. The lower residential land costs in Windward Oahu as compared with Honolulu.

3. The marked improvement of two highways to the windward side.

4. The employment and business which result from the Kaneohe Marine Corps Air Station.

According to the Planning Department, City and County of Honolulu, projections show that the population in the watershed will reach 10,000 in 1975 and 16,500 in 1985. These projections are based on the influencing factors of population growth mentioned earlier.

There are 69 farms in the watershed, of which 35 are family-type employing less than 1-1/2 man-years of outside labor. The farms are generally small operations averaging 6 acres in ownership.

The Kahaluu watershed is an integral part of the Kualoa-Kahaluu area which has been designated as one of the "target areas" by the Hawaii Office of Economic Opportunity (OEO). About 21 percent of the watershed families have incomes of less than $4,000 per year. Although this area shows a smaller population than neighboring census tracts, the number of persons on welfare is comparatively higher. As of June 1965, there were 170 active cases, most of which are located in the watershed area.

The 1960 U. S. Census counted 1,257 homes in the census tract. Approximately 43 percent were considered as deteriorating or dilapidated. About one-half of this total is in the watershed. The median schooling for the population living in the census tract is 9.7 years. According to the School and College Ability Test

administered to fourth graders at Kahaluu Elementary School during the 1964-1965 school year, the students scored at the 31st percentile band for both the verbal and quantitative parts. By comparison, the state average was at the 64th percentile band.

Agriculture and Related Activity

The agricultural operations are primarily oriented to the production of taro, papaya, banana, and various truck crops. Tropical flowers and ornamental plants are also produced commercially. Other agricultural operations include a dairy and several poultry and livestock farms.

About 52 percent of the taro grown on Oahu is produced in the Kahaluu watershed. Because of the drastic decrease of taro acreage and production on the neighbor islands, the outlook for Kahaluu taro farmers should appear bright. The threat of floods, however, has tended to negate any of the projected increase in taro acreage in the watershed.

Besides growing taro, most of the remaining agricultural operations are in pasture and truck farms. Highly market-oriented, the farms mainly grow snap beans, Manoa lettuce, cucumber, and daikon. These crops can be harvested as many as four times a year with yields as follows:

Crop	Yield/Acre/Crop (lbs.)
Snap beans	6,000
Cucumber	10,000
Manoa Lettuce	12,000
Daikon	20,000

The gross value of truck crops averages between $10,000 and $20,000 per farm per year.

Employment

There is a critical need for off-farm employment in the watershed. The 1960 Census listed 1,171 in the male civilian population, of which 6.2 percent were unemployed; the female labor force of 518 had an unemployment fate of 13.0 percent. Comparatively, the entire island had a male unemployment rate of 3.0 percent while the female unemployment rate was 5.2 percent.

Land Values and Ownership

Cropland is valued at an average of $.20 a square foot or approximately $8,700 an acre. Unimproved residential-zoned land has an average market value of about $12,000 an acre. Commercial land is valued at $1.10 a square foot or approximately $48,000 an acre. The high values are caused by the relative scarcity of developable land because of the island's steep terrain and the control of a large part of the land by large holdings.

Land ownership in the watershed is distributed as follows:

	Percent	Acres
Private	62	2,740
Forest Reserve (City & County of Honolulu)	37	1,640
Other Public Lands	1	40

Transportation

The populated sections of the watershed are well-knitted with public and private roads. The Kamehameha Highway traverses the coastline connecting the town of Kahaluu with the city of Honolulu, the Kaneohe-Kailua-Lanikai complex, and the towns along the northern coastline. The Kahekili Highway, scheduled for completion within two years, will provide a second faster route to the city of Honolulu.

Although the small boat harbor at Heeia is 4 miles to the southeast, it is not generally used for transportation of goods into or from the watershed. Highway transport is the principal mode of shipping to the Honolulu terminals.

Land Treatment Data

At the turn of the century, rice was the second largest agricultural crop in the state. The bottom lands of watersheds with perennial streams, such as at Kahaluu,

were characterized by patchworks of rice paddies. Farmsteads, a rice mill, a grocery store or two and a church typically made up the valley communities. Few homes, if any, were built on the hillsides or upper watershed.

It wasn't long before the large-scale mechanized rice farms in California spelled the doom of Hawaii's rice industry. Taro farms replaced a few of the rice fields, but mostly, the land was returned to grass and became pastureland. Streambeds soon were encroached upon by the thicket-forming hau trees, java plum trees, and other vegetation which the rice farmers had earlier kept in control. Obstructed flood flows eroded the streambanks and inundated large areas of the flood plain. Presently, floods of the magnitude of that which occurred on May 2, 1965--about the six percent chance of occurrence--will cause inundation of 230 acres of the lower flood plain.

The population movement into the Kahaluu area in the early 1960's followed the general pattern of suburban developments in Hawaii. Home builders sought out the less expensive hillside lands and carved in their developments. The common practice of denuding large tracts of land at one time then cutting and filling to create houselots was generally practiced in the valley. A grading ordinance to restrict such widespread scarification of the island's landscape was enacted by the City Council in 1965. However, it was too late to prevent some of the land damage, characterized by scarred areas of red soil along the valley hillside.

A recent survey in the watershed showed a total of 280 acres of land presently exposed. Of this, SCS scil scientists have determined that 166 acres are active sediment sources.

The upper watershed is comprised of restricted forest reserve land. This area is characterized by dense forest cover with stable rock outcrops on the steep mountain slopes. Owned by the City and County of Honolulu, its use is regulated and administered by the Department of Land and Natural Resources of the State of Hawaii. The use restrictions have been established to protect the ground water supply source developed by the Honolulu Board of Water Supply.

The Windward Oahu Soil and Water Conservation District has been instrumental in bringing about conservation works to the farms of the area. They have been engaged in other activities designed to bring improvements into the district under various State and Federal programs. There are 26 District cooperators presently in the watershed, seven of whom have completed basic plans. In addition, a Memorandum of Understanding exists between the District and the Department of Land and Natural Resources to provide for technical assistance in the forest land. The above farms and forest land comprise 58 percent of the total watershed area.

This home was carried one-fourth mile downstream and crushed against the Kamehameha Highway bridge over the Kahaluu Stream SCS Photo 4-862.1

WATERSHED PROBLEMS

The threat of damaging floods is a serious problem in the watershed. Twenty floods have occurred in the 32-year period from 1936 to 1969. Damages to agricultural, residential, commercial and industrial improvements have resulted from the high velocity flood flows through the area. Flooding also represent a constant threat to life. One drowning occurred during the height of the storm of December 1966. Five people were saved in 1965 after they were swept into the raging Kahaluu Stream. The destruction of roads, bridges and homes has become a common occurrence during floods. In April 1963, one bridge and one home were completely demolished. In two 1965 floods, three bridges and five homes were demolished and numerous other homes were moved off their foundations. The mental anguish of the occupants of these homes is immeasurable. The fact that no lives were lost in these floods is miraculous.

The storm of May 1965, which was about a 17-year frequency event, is representative of the large floods in the watershed. Approximately 250 acres were inundated with the following distribution of direct damages:

	Damages (Dollars)	Percent of Damages
Agricultural	77,256	24
Residential	81,202	25
Commercial & Industrial	55,736	17
Roads and Bridges Public Agencies	108,000	34
Total	322,194	100

Other non-monetary damages were recorded. Many homes were isolated by damaged or destroyed bridges. The water main was broken for many hours creating a health hazard. Land transmission lines used by the military communications system, vital in case of military emergencies, were inoperative for several hours. Rescue operations by various agencies, such as the City and

County Fire Department, saved many lives. The U. S. Marine Corps and the Hawaii Army National Guard also aided in these operations, using amphibious vehicles and helicopters. Fortunately no lives were lost; however, had the flood occurred during the hours of darkness, the outcome could have been tragically worse.

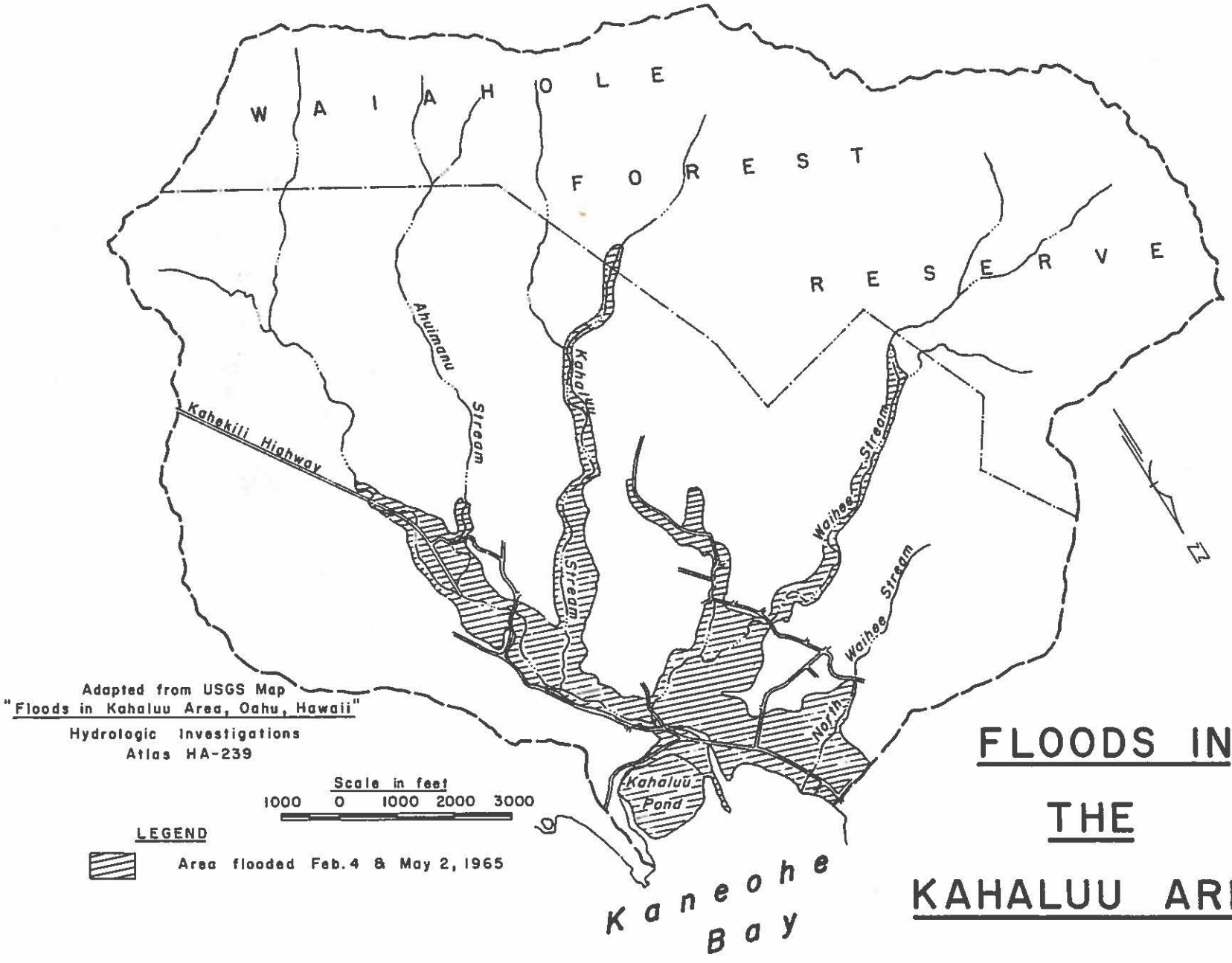
The small, more frequent floods overtop the channels and cause shallow waters to spread over an area of about 100 acres. The scouring effect causes considerable damage to residences, roads and bridges. These floods deposit sediment in yards, farmlots and commercial establishments causing additional damage and inconvenience.

The storm of November 1965 produced a small flood typical of about a 3-year frequency event. The following table illustrates the distribution of direct damages caused by this flood:

	Damage (Dollars)	Percent of Total Damage
Agricultural	9,619	60
Residential	1,103	7
Commercial & Industrial	3,276	20
Roads & Bridges	2,100	13
Total	16,098	100

Damages caused by erosion and sedimentation are becoming an increasingly serious problem in the watershed. Erosion and sediment deposition is widespread due to the extremely high sediment yield from the upper watershed. Areas denuded by the early tract developers have intensified the problem.

Erosion and sediment damages to the principal crops produced in the watershed occur with every storm. Losses incurred on taro, banana and other vegetable crops are increasing. Large acreages of once prime taro lands have been converted to lower-income crops such as pasture or forage because of the sediment and weed infestation problem.



FLOODS IN THE KAHALUU AREA

Soiled laundry and accumulated debris give silent evidence of the flood through this residential area.

SCS PHOTO 4-878-1

This house was carried downstream approximately 200 feet by the flooding Waihee Stream. Note also the Army trucks used for rescue operations.

SCS PHOTO 4-877-1

Natural channels in the flood plain have relatively flat gradients and very low drainage capacities. The low capacity is caused by a lack of maintenance and the natural topography. Sediment deposition occurs in the stream channels and is usually caused by debris or brush choked conditions. Thus channel capacities are reduced, and the overbank flood hazard is increased, with each storm.

Overland flows, regardless of magnitude, have sustained velocities sufficient to cause serious erosion and transport significant sediment loads. The effects of the high sediment load in the floodwaters are demonstrated by the hundreds of man-hours required for clean up after each flood.

Floods and the threat of future floods in the watershed have depressed the agricultural activity in the bottom land. The major floodwater damage is the loss of crops. Additional damage can be attributed to debris deposition, spreading noxious weeds, damages to farm improvement and loss of livestock. Farmers in this area have found the former rice paddies ideal for growing taro. Poi, the Hawaiian food staple, is processed from taro. The State Department of Agriculture stated that the early 1966 flood season caused an estimated 25 percent drop in the state's poi production for that year. Floods in the watershed have contributed to a 50 percent reduction of taro acreage on the island of Oahu.

An additional effect of sediment has recently been described by marine biologists at the University of Hawaii Marine Laboratory in Kaneohe Bay. Sediment deposition has inflicted harmful effects on the marine fauna by suppressing further development of coral formation in the sediment outfall areas.

There is a definite lack of adequate recreational facilities in the watershed. According to the Honolulu Department of Parks and Recreation, the Kahaluu community is now served by a small neighborhood school-park complex which is limited in size and unable to provide a balanced recreational program for all age groups. This problem has become more pronounced since the population has more than doubled during the last ten years. Recognizing that the streams in the watershed are presently being

This taro crop was lost and field practically destroyed by flood and debris.

SCS PHOTO 4-880-9

This banana field was damaged when the nearby stream overflowed its banks.

SCS PHOTO 4-881-11

used by neighborhood children as water recreation areas, the City and County of Honolulu suggested that the proposed stream channel improvement be considered for recreational use. They contracted with the planning firm of Donald Wolbrink and Associates, Inc., to study the feasibility of incorporating a park system in the Kahaluu Watershed Project. The Kahaluu Stream Park Feasibility Study was released in May 1968 and found the multiple-purpose use of the stream for recreation and flood prevention to be favorable.

Section of Ahuimanu Road completely destroyed by flooding in Kahaluu Stream. SCS PHOTO 4-877-10

PROJECTS OF OTHER AGENCIES

The U. S. Army Corps of Engineers has completed emergency bank protection along the Kahaluu Stream near the Kamehameha Highway. The rock-masonry work, installed in 1967, will protect the abutment of the highway bridge and check further streambank erosion in this area pending installation of the Kahaluu stream channel improvement.

The State Highway Department has proposed to extend the partially-completed Kahekili Highway to the Kamehameha Highway. (See Figure 4.) The extension will involve the crossing of the Ahuimanu (A-1) stream channel improvement. The Highway Department and the Soil Conservation Service have coordinated designs in the proposed works of improvement. Approximately 530 feet of the A-1 channel and a diversion channel of the Ahuimanu stream tributary will be installed by the Highway Department as part of their works. Contract for the highway extension is scheduled to be let during 1969.

This lined channel in the Waianae-Nui Watershed is typical of the channels proposed for flood prevention in the Kahaluu Watershed.

SCS PHOTO 4-1003.8

PROJECT FORMULATION

Project Objectives

Formulation of the project work plan was based on the objectives set forth by the sponsoring local organizations. These objectives, initially described by the Kahaluu Flood Control Committee, included flood prevention, treatment of the eroded lands, and the enhancement of the social and economic development of the community.

Land Treatment Measures

Land treatment measures will provide necessary conservation, development, and improvement in the watershed. The measures are those needed to stabilize land and to help the farm operators obtain optimum land use and production efficiency.

Rapid urban growth will continue to retire land from agricultural use and cause more intensified use of the remaining cropland. Changes in agricultural use may require additional land treatment measures to protect the soil from erosion and maintain fertility.

Heavy emphasis will be placed on a land treatment program in existing sediment source areas. Some of these areas are in agriculturally-zoned land in residential use. The directors of the Windward Oahu Soil and Water Conservation District and the Kahuluu Flood Control Committee are spearheading a proposal which will provide watershed protection through erosion control and reduction of sediment production from new land development areas. This program includes contacting landowners with erosion problems and suggesting means for obtaining technical assistance from the SCS.

In January 1968, the State of Hawaii enacted water quality regulations which included regulatory procedures to abate water pollution, classification of uses of all state waters, and water quality standards. The standards comply with the Water Quality Act of 1965.

Included in the regulations for all state waters is the requirement that:

> "All waters shall .... be free from soil particles resulting from erosion on land involved in earthwork, such as the construction of public works, highways, subdivisions, recreational, commercial, or industrial developments, or the cultivation and management of agricultural lands. This standard will be deemed met if it can be shown that the land on which the erosion occurred or is occurring is being managed in accordance with soil conservation practices acceptable to the Director, and that a comprehensive conservation program is being actively pursued, or that the discharge has received the best practicable treatment or control."

The land treatment goals will help land users to comply with the above water quality regulation. This will involve planning an adequate soil conservation program and installing planned practices within the 5-year project installation period.

Structural Measures

The sponsors and the Service have agreed that the desired level of flood protection should be the 100-year frequency of occurrence. The basis for this decision includes the following: (1) the loss of life is a serious threat, (2) the high velocity flood flows result in considerable damage, (3) the high level of protection will prevent most of the damages in the flood plain area and will induce greater development of this area.

A survey was made to locate possible floodwater retarding sites. The steep topography of the upper watershed precluded satisfactory storage sites for flood protection. Engineering investigations then proceeded toward obtaining the desired protection by improving the main stem of the lower Kahaluu, Waihee, and Ahuimanu streams with a channel system. Alternatives of lined and unlined sections of rectangular and trapezoidal channels were considered. In most cases, relatively high land costs and the steeper slopes favored the lined sections. Benefit to cost analyses were made and the evaluation units showing better than a one-to-one ratio were included in the structural works of improvement for flood prevention.

The recreational plan is the result of a cooperative effort by the Honolulu Department of Parks and Recreation and the Soil Conservation Service. The plan will serve to meet the recreational development goals for the area, as set forth in the county's long range comprehensive parks and recreation program. The primary purpose of the recreational measures is to provide opportunities for water-based activities. Full consideration was given to community and county needs and to statewide plans for the orderly development of the recreation resources.

The multiple-purpose flood prevention and recreational development will be the first of its kind in the state. This unique development will be accessible for use by the inhabitants and visitors of the entire island of Oahu.

WORKS OF IMPROVEMENT TO BE INSTALLED

Land Treatment Measures

The measures to be applied are those required to stabilize and improve lands for present and future needs. The Soil Conservation Service has completed a survey of the soils in the watershed. Technical guides have been developed by the SCS describing soil capabilities and land treatment measures. The SCS Honolulu work unit staff will assist landowners and operators in planning and installing the needed land treatment.

Measures to be installed on cropland and orchard land include: conservation cropping system to improve the tilth and increase the permeability of the soil, crop residue management to protect the topsoil from wind and water erosion, and contour farming to reduce erosion and provide water control.

On grassland, these practices will be applied: brush control to reduce competition of woody plants; pasture management to prolong the life of the desirable forage species, maintain or improve the quality and quantity of forage, provide soil protection, and reduce water losses; and pasture planting to improve or replace poor and low-producing stands.

Forestry measures will include restoration of vegetative cover; protection from livestock damage; tree planting for timber production, watershed protection and recreation sites; and stabilization of eroded slopes and forest roads.

On other lands, critical area planting will reduce erosion and the siltation of downstream areas. Hillside ditches will control the flow of water above the critical areas. These practices will be planned for the steep, erodible slopes in the housing subdivisions and other developments.

Structural Measures

The structural measures for flood prevention will supplement the land treatment program in reducing the floodwater, sediment and erosion damages in the flood plain area. Tables 1 and 2 list the cost distribution of the proposed measures by the types of structures and by the individual structure systems, respectively. Tables 3 and 3A list the design features of the various structural measures. Figures 4 to 8 show the plan, profile and cross sections of the channel structures. The locations of the structures are shown on the Project Map.

The channel improvements were designed to control the flood flows and prevent flooding of the lower sections of the watershed. The design capacities will allow channeling of storm runoff for up to and including the one percent chance of occurrence.

Approximately 14,010 feet of reinforced concrete channels will be installed on the North Waihee Stream and the tributary reaches of the Waihee, Kahaluu and Ahuimanu streams. The latter three channels will flow into a broad, grass-lined lagoon. At the Kamehameha Highway, the lagoon will transition into a 280-foot channel with rock-lined sides to outlet into Kaneohe Bay.

Floodwaters in the tributary channels will be flowing at high velocities. Two energy dissipating structures will be installed at the points where the channels enter the lagoon. These structures will be designed according to criteria developed by the USDA Agricultural Research Service at the Saint Anthony Falls Hydraulic Laboratory. A typical structure is shown in Figure 5.

Debris basins to prevent rocks and boulders from entering into the channel systems will be installed at the inlets to the Kahaluu and the Waihee channel tributaries. The basins are located at sections of the stream where the natural topography will demand a minimum amount of excavation to obtain storage capacity. Flows from the basins will be controlled by vertical-walled inlet structures (Figure 6). The debris storage capacities, shown on Table 3, are such that maintenance will be required only after extremely heavy storms.

The 28-acre lagoon will serve the multiple-purposes of flood prevention and water-based recreation. The lagoon will be excavated to a depth allowing tidal ebb and flow of the Kaneohe Bay waters. Excavation at the mouth of the channel will be required to maximize water circulation and to minimize channel accretion during storm flows. A narrow channel will be excavated out to deep water to allow boat passage during low tides. The lagoon banks will be sloped at three-to-one and planted with a salt-tolerant grass. This will allow the full and safe use of the shoreline of the lagoon. Fencing for the protection and safety of the public will be installed on the energy dissipating structures and upstream channels in the proximity of the recreational development.

Recreational facilities will be installed in the 22 acres surrounding the lagoon. Designed by the City and County of Honolulu Department of Parks and Recreation, the facilities include trails, roads, parking areas, comfort stations, picnic sites and a boat ramp. Landscaping of the recreational area will be designed to maintain a tropical atmosphere and to blend with the nearby mountains and the adjacent ocean.

Six reinforced concrete bridges and culverts to replace existing road crossings will be included in the channel construction contracts. All bridge and culvert construction plans and specifications will be prepared by the City and County of Honolulu. The Ahuimanu Road crossing is presently under design and is scheduled for installation before project construction. In addition, the Kahekili Highway crossing will be installed with the highway construction contract in 1969.

A total of 25 homes will be affected in the construction of the structural measures. Thirteen of these will be relocated and twelve will be demolished. Construction will also require the relocation of a 30-inch water main along the Kamehameha Highway at the North Waihee and the KA-1 Lagoon crossings. A portion of the existing Ahaolelo Road will be relocated upstream of the lagoon.

During installation and operation and maintenance of the planned structural measures, the sponsors will assure compliance with the County grading ordinance and the State water quality and health regulations.

Artist's concept of the Kahaluu Lagoon - Park complex

SKETCH COURTESY OF
DONALD WOLBRINK & ASSOCIATES, INC.
HONOLULU, HAWAII

EXPLANATION OF INSTALLATION COSTS

Land Treatment Measures

The installation costs for land treatment measures on the four classifications of land are shown in Table 1. These are estimates of total costs for establishing prescribed measures over the five-year installation period. The estimated total cost is $955,670. This includes $875,230 to be borne by others in applying the measures. The remaining costs of $80,440 provides for technical assistance by the Soil Conservation Service and Forest Service to the landowners and operators in the watershed. The PL-566 share of this cost, estimated at $68,610, will absorb the expenses of providing this assistance at an accelerated rate to meet the five-year schedule. The other portion, estimated at $11,830 is the normal SCS and State Forestry Division costs under their going programs.

The cost estimates for installing the land treatment measures, including technical assistance, are projected from current costs and past experience in applying similar measures in the state.

The standard soil survey of the Kahaluu watershed has been completed by the Soil Conservation Service. No project costs are anticipated for the acquisition of further soil survey information for the planning of land treatment measures.

Structural Measures

The installation costs for structural measures are shown in Tables 1 and 2. These costs include estimates of all expenditures to be incurred in the construction, engineering services, project administration and the land rights required for the installation of the structural measures.

The construction costs of the structures were separated into the various units of construction and these costs were estimated from unit prices paid on similar projects. Costs were increased by about 15 percent for contingencies. The total construction cost allocated for flood prevention is $3,572,760

and will be borne by PL-566 funds. The total construction cost allocated for recreation is $336,340, of which PL-566 and other funds will equally cost-share at $168,170.

Installation costs for the multi-purpose channel system, including those for engineering services and land rights, were allocated either to flood prevention or to recreation. The allocation procedure required first obtaining the cost estimate for the installation of a single-purpose flood prevention channel improvement. This cost was allocated to flood prevention. The difference in installation costs of the total multi-purpose channel system and the single-purpose channel improvement was allocated to recreation. The installation cost of the basic recreational facilities was allocated to recreation.

Engineering costs include those for engineering surveys, investigations, structural design and related activities. Except for the basic recreational facilities, all engineering costs for structural measures will be borne by PL-566 funds. Estimated PL-566 cost is $432,400 and other cost is $27,670.

Land rights costs include all expenditures for the acquisition of land, easements, and rights-of-way, for necessary construction of bridges and for relocation of roads, homes and utilities. Land rights acquisition costs were estimated after consulting with the City and County of Honolulu Department of Public Works. All land needed for structural measures and for recreational facilities will be purchased in fee simple title. Bridge construction and other costs were based on past PL-566 and similar projects.

ALL FLOOD AREA

Total land rights cost is estimated at $1,961,180, of which $1,568,250 is allocated to flood prevention and $392,930 to recreation. All flood prevention land rights costs will be borne by other funds. Recreation land rights costs, excluding engineering, legal and administrative costs for acquiring the needed land, will be cost-shared equally by PL-566 and by other funds. The recreation land rights cost to be borne by PL-566 funds is $195,470. The cost borne by other funds is $197,460 including $1,990 for engineering, legal and administrative costs.

The above land rights costs allocated to recreation include payments to landowners for about 25 acres of land and for the relocation of two homes. This cost sharing for land rights falls within the limitation of not more than 50 acres of land per mile of stream.

Project administration costs include expenditures for activities such as contract administration, construction surveys, review of engineering plans prepared by others, and construction inspection services. Estimated PL-566 cost is $374,090 and other cost is $236,350.

Total installation cost for structural measures is $6,940,790, of which $4,742,890 will be borne by PL-566 funds and $2,197,900 by other funds.

The estimated funds needed are shown on the following schedule for the project installation:

Fiscal Year	Activity	FUNDS (Dollars) PL-566	Other	Total
First	land treatment	11,790	143,630	155,420
	structural	375,690	121,570	497,260
Second	land treatment	14,470	182,700	197,170
	structural	1,644,690	1,586,420	3,231,110
Third	land treatment	19,830	260,830	280,660
	structural	865,460	179,720	1,045,180
Fourth	land treatment	17,160	221,770	238,930
	structural	1,142,460	256,190	1,398,650
Fifth	land treatment	5,360	78,130	83,490
	structural	714,590	54,000	768,590
Total Land Treatment		68,610	887,060	955,670
Total Structural		4,742,890	2,197,900	6,940,790
TOTAL PROJECT COST		4,811,500	3,084,960	7,896,460

EFFECTS OF WORKS OF IMPROVEMENT

The proposed land treatment measures will promote the basic goals of the Windward Oahu Soil and Water Conservation District by encouraging the best use of the land while providing for the maximum protection of the soil. These measures will help improve land conditions, encourage efficient farm management, and will allow the maximum benefits to be derived from the installation of the structural measures. Failure to install the land treatment measures will contribute to the sediment pollution of the streams and bay in violation of the state water quality regulations.

Measures such as conservation cropping system and crop residue management on the cropland will improve soil structure and increase fertility while providing protection from wind and water erosion. Pasture management on the grassland will promote better forage and provide soil protection.

Reforestation will improve the watershed cover in the forested area with the effects of enhancing the scenic and recreation values, and wildlife habitats. On lands suitable for commercial forest, tree crops will be considered as economic enterprises.

The residential areas will require measures that must be installed by individual or groups of home owners. These measures will stabilize a major source of sediment and minimize damages to the homes, businesses, roads, and other improvements. In addition, the measures will heal the erosion scars and beautify the landscape.

The proposed structural measures are designed to contain the runoff from storms up to and including the 100-year frequency of occurrence. The area benefited by these measures encompasses 323 acres. (See Project Map.)

Included in this area are 10 businesses, 89 residences, 35 farms and 4 utilities installations. Total value of the homes, businesses and other improvements, including highways and bridges is estimated to be over $6.7 million. Fully developed improvements, under projected conditions, would have a market value of $64.6 million. These improvements are based on the future land use under the present zoning.

Approximately 70 acres of the remaining flood-prone land will still be subject to damage during major storms. These are areas along the streams above the limits of the structural works of improvement. Although mostly undeveloped, some small acreages of pasture and cropland will still be affected. Other unprotected works include Board of Water Supply transmission lines and roads in the upper watershed.

The multi-purpose park-lagoon complex will provide water-based recreation facilities for island residents as well as tourists visiting the north shore resort areas. The climate allows the park to be used all twelve months of the year. The Honolulu Department of Parks and Recreation has estimated that the park will annually draw 95,000 visitor-days from the resident population. These users will be picnickers, fishermen, boaters and others who will spend a considerable part of the day at the development. The number of tourists expected to use the facilities is estimated at 120,000 annually. This reflects the maximum number allowable with the proposed facilities. Under the projections for tourists visiting the north shore, the potential park visitors may increase ten-fold. The sponsors may eventually desire to increase park facilities to accomodate a portion of this projected increase.

PROJECT BENEFITS

The total average annual flood damage was estimated at $347,550. With the installation of works of improvements, the damage will be reduced to $1,570. The difference of $345,980 is flood damage reduction benefits attributable to the proposed land treatment and structural measures (see Table 5).

The land treatment measures under the proposed accelerated program will reduce flood damage by about $14,130 annually. Benefits derived from flood prevention structural measures will be $356,060. This includes primary benefits of $331,850 and secondary benefits of $24,210 (see Table 6).

Average annual benefits attributable to recreation measures will be $160,330. This includes primary benefits of $144,810 and secondary benefits of $15,520. These benefits will be realized by residents of the City and County and tourists visiting the island.

Average annual secondary benefits of $39,730 will accrue to farms and other enterprises within the immediate zone of influence. These benefits relate directly to the increase and stabilization of the transporting, processing and marketing of goods and services stemming from the project. Secondary benefits from a national viewpoint were not considered in the economic evaluation of the project.

The installation of the land treatment and structural measures will encourage additional interest in conservation of the resources of the watershed. Although unevaluated as a project benefit, restoring the scarred hillsides will help to beautify the area and have esthetic benefits. The project will also promote further capital improvements, increase employment, help the low-income residents to achieve higher standards of living, and contribute to the general welfare of the community and the state. Militarily, the protection to the U. S. Army communications cable which crosses the Kahaluu Stream may have national implications. Perhaps the most important unevaluated benefit to be derived from the project is the protection of human life.

COMPARISON OF BENEFITS AND COSTS

The average annual benefits accruing to the structural measures are estimated to be $516,390. The average annual cost of these measures is $386,450. The ratio of benefits to cost is 1.3 to 1.0, including local secondary benefits.

The benefit to cost ratio without the inclusion of secondary benefits is 1.2 to 1.0.

The benefits and cost for the project flood prevention and recreation measures are shown in Table 6.

PROJECT INSTALLATION

The execution of this plan will be a joint undertaking of private, local and Federal interests. Land treatment measures will be installed by individual landowners cooperating with the Windward Oahu Soil and Water Conservation District. Technical assistance will be given by the Soil Conservation Service and the State Division of Forestry through the Forest Service.

The structural measures will be installed by the City and County of Honolulu with the assistance of the Soil Conservation Service.

The sponsoring local organizations and the Soil Conservation Service have agreed to the following specific responsibilities for the project installation:

The Windward Oahu Soil and Water Conservation District will:

1. Provide local leadership and direction which will continue the going conservation program of the District.

2. Provide local leadership to insure the scheduled installation of the accelerated land treatment program on private lands.

Goals for planned land treatment work during the installation period will give first priority to needed practices and measures in the Ahuimanu, Kahaluu and Waihee subwatersheds. The District will stress planning and application of land treatment through special meetings and personal contacts. The Kahaluu Flood Control Committee provides an organization through which the District program can be brought directly to the landowners.

The schedule of land treatment over the five-year installation period is:

Fiscal Year	Number of basic conservation plans to be developed	Percent of planned practices and measures to be applied
First	27	15
Second	27	20
Third	30	30
Fourth	27	25
Fifth	16	10
Total	127	100

The City and County of Honolulu will:

1. Survey, acquire and record all necessary land, easements and rights-of-way for the structural measures.

2. Act as contracting local organization for the construction of the structural measures. If, during the installation period, federal administration of contracts are desired, the City and County of Honolulu will make necessary arrangement with the Soil Conservation Service.

3. Design and install all bridges or road crossings required on county roads for the structural measures. Insure the installation of state highway crossings. Maintain or provide for maintenance of these structures.

4. Provide for the installation, operation and maintenance of all the structural measures. Replace recreational basic facilities as needed.

5. Furnish the remaining non-Federal share of the cost and services for the project structural measures as shown on Tables 1 and 2. This includes the other share of construction costs for the multi-purpose channel system and basic recreational facilities, engineering services for the basic facilities and utility relocations, and other project administration costs.

Prior to the release of invitations to bid, agreements shall be executed between the sponsors and the Soil Conservation Service. These agreements will cover all commitments of responsibilities of all parties, including but not limited to, those items pertaining to financing, inspection and maintenance. Full conformance with State and Federal laws and regulations will be the responsibility of non-Federal interests.

The City and County of Honolulu has the power of eminent domain, can form improvement districts and assess taxes for the improvements, can receive gifts and contributions and can issue bonds for county improvements. The required land, easements and rights-of-way will be acquired by negotiation or, if necessary, by condemnation action. With the sponsor's agreement to use such powers, P.L. 566 assistance for construction may be provided before all necessary land rights for the project, or for a construction unit, are obtained.

The sponsoring local organizations have given the Soil Conservation Service adequate assurance that their share of project costs will be available as required and that acquisition of land rights for the first two years of construction will commence as soon as possible.

The Soil Conservation Service will:

1. Furnish necessary technical assistance through the Windward Oahu Soil and Water Conservation District to private landowners in installing land treatment measures as scheduled in the work plan.

2. Furnish the necessary engineering survey and design services for all the structural measures, except the basic recreational facilities.

3. Furnish the necessary project administration services to assure that structural works installation will conform to acceptable standards.

4. Allot construction money to the project in accordance with the time schedule set forth herein, or as revised by mutual agreement and in accordance with national priorities and availability of appropriations at the time of installation.

5. Maintain liaison with the sponsoring local organizations, State, and other Federal agencies involved in the project to the end that unified efforts and coordinated action will produce the most effective results.

6. Consult with and assist the sponsoring local organizations in making desired revisions of the plan.

The schedule for installation of structural measures follows:

SCHEDULE FOR INSTALLATION OF STRUCTURAL MEASURES

MEASURE	ITEM	FISCAL YEAR				
		FIRST	SECOND	THIRD	FOURTH	FIFTH
NW Channel	DESIGN LAND ACQUISITION CONSTRUCTION					
KA-1 Multi-purpose Channel System and SAF Basins	DESIGN LAND ACQUISITION CONSTRUCTION					
W-1 & W-2 Channels	DESIGN LAND ACQUISITION CONSTRUCTION					
A-1 Channel	DESIGN LAND ACQUISITION CONSTRUCTION					
Recreational Basic Facilities	DESIGN LAND ACQUISITION CONSTRUCTION					
KA-2 Channel	DESIGN LAND ACQUISITION CONSTRUCTION					

The following State and Federal agencies, by agreement with the sponsors, will participate as follows:

The U. S. Forest Service will:

Cooperate with the State Forester in providing tree planting stock and furnishing technical assistance for land treatment on all non-Federal forest land.

The Board of Land and Natural Resources will:

1. Through its Division of Water and Land Development, assist the sponsors, as needed to accomplish the work plan.

2. Through its Division of Forestry, in cooperation with the U.S. Forest Service, provide technical assistance in reforestation practices in the 2,060 acres of forest lands under the use jurisdiction of the Department.

The Agricultural Stabilization and Conservation Service Committee, State and County, will:

Give high priority to scheduling ACP funds to expedite the land treatment measures on private lands.

FINANCING PROJECT INSTALLATION

Land Treatment Measures

The cost of installing the land treatment measures will be borne by the landowners and operators. Accelerated cost-sharing assistance to farmers may be provided through the U.S.D.A. Agricultural Conservation Program.

Technical assistance will be provided by the Soil Conservation Service and the State Division of Forestry with going program funds. Additional P.L. 566 funds will be available to the Soil Conservation Service and the Forest Service to implement the plan for accelerated technical assistance.

Structural Measures

The City and County of Honolulu, under the Revised Laws of Hawaii, 1955, has authority to carry out, maintain and operate flood control and park development projects. Funds needed to carry out its obligations, as defined in this work plan and agreed to in the Watershed Work Plan Agreement, will be provided through the Honolulu Capital Improvement Projects budget. The sponsors do not propose to use the loan provisions under the Watershed Protection and Flood Prevention Act.

Federal assistance for carrying out the works of improvement will be provided under the authority of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress; 68 Stat. 666), as amended. Financial and technical assistance to be furnished by the Federal Government is contingent on the appropriation of funds for these purposes.

PROVISIONS FOR OPERATION AND MAINTENANCE

Land Treatment Measures

Land treatment measures will be maintained by the owners or operators of the lands on which the measures are installed. Technical assistance for the maintenance of the measures will be provided by the Soil Conservation Service and the Forest Service through the Windward Oahu Soil and Water Conservation District.

Structural Measures

The operation and maintenance of all structural measures will be the responsibility of the City and County of Honolulu. An operation and maintenance agreement will be executed between the City and County of Honolulu and the Soil Conservation Service prior to signing of project agreeements.

The City and County of Honolulu will be responsible for obtaining rights-of-entry or other instruments, where needed, to allow access to the easements or rights-of-way of the structures. Access to these areas will be solely for operation and maintenance functions and for inspection of the structures.

The maintenance program will include the preservation of the design capacities of channels, debris basins and other structural components for flood prevention. It will also include the repair, upkeep and needed replacement of all basic facilities installed as part of the recreational development. Although no major repairs are foreseen, the basic facilities installed will need the upkeep work normally expected for these facilities. This cost and the replacement costs, based on the Parks Department experience, will annually amount to $30,800. The total estimated annual cost for operation and maintenance is $61,900.

The City and County of Honolulu and the Soil Conservation Service will jointly inspect all structures annually, or after unusually severe floods, for three years following installation of each structure. If during this period, major repairs are required because of deficiency in the structure design, the Service may bear part of the cost of the repair. All annual and other inspections after the third year will be made by the City and County of Honolulu and a report will be submitted to the Soil Conservation Service, Honolulu Work Unit, stating corrective measures needed and actions taken.

TABLE 1 - ESTIMATED PROJECT INSTALLATION COSTS

Kahaluu Watershed, Hawaii

Installation Cost Item	Unit	Number Non-Fed. Land	Cost (Dollars)1/ Non-Federal Land PL-566	Non-Federal Land Other	Non-Federal Land Total
LAND TREATMENT					
Soil Conservation Service					
Cropland	Ac.	158	--	56,500	56,500
Grassland	Ac.	509	--	149,170	149,170
Miscellaneous Land	Ac.	490	--	569,560	569,560
Technical Assistance			53,610	6,080	59,690
Subtotal - SCS		1,157	53,610	781,310	834,920
Forest Service					
Forest Land	Ac.	2,060	--	100,000	100,000
Technical Assistance			15,000	5,750	20,750
Subtotal - FS		2,060	15,000	105,750	120,750
TOTAL LAND TREATMENT		3,217	68,610	887,060	955,670
STRUCTURAL MEASURES					
Construction					
Soil Conservation Service					
Stream Channel Improvement	Ft.	14,010	2,272,760	--	2,272,760
Debris Basins	No.	2	87,460	--	87,460
SAF Basins	No.	2	358,640	--	358,640
Multi-Purpose Channel System (Lagoon)	Ft.	3,060	883,740	29,840	913,580
Recreational Facilities	No.	1	138,330	138,330	276,660
Subtotal - Construction			3,740,930	168,170	3,909,100
Engineering Services					
Soil Conservation Service			432,400	27,670	460,070
Project Administration					
Soil Conservation Service					
Construction Inspection			115,970	100,000	215,970
Other			258,120	136,350	394,470
Subtotal - Administration			374,090	236,350	610,440
Other Costs					
Land Rights			195,470	1,765,710	1,961,180
TOTAL STRUCTURAL MEASURES			4,742,890	2,197,900	6,940,790
TOTAL PROJECT			4,811,500	3,084,960	7,896,460

1/ Price base: 1968

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TABLE 1A - STATUS OF WATERSHED WORKS OF IMPROVEMENT

Kahaluu Watershed, Hawaii

Measures	Unit	Applied To Date	Total Cost (Dollars) 1/
LAND TREATMENT			
Conservation Cropping System	Ac.	30	150
Cover and Green Manure Crops	Ac.	20	600
Crop Residue Use	Ac.	100	1,000
Land Smoothing	Ac.	6	360
Stream Channel Improvement	Ft.	710	1,420
Irrigation Pipeline	Ft.	3,000	6,750
Drainage Field Ditch	Ft.	2,470	2,470
Tile Drain	Ft.	9,340	63,510
Pasture and Hayland Management	Ac.	30	900
Pasture and Hayland Renovation	Ac.	30	1,200
Land Clearing	Ac.	108	6,480
Critical Area Planting	Ac.	19	49,940
STRUCTURAL MEASURES			
Stream Channel Improvement	Ft.	4,800	340,000
Streambank Protection	Ft.	1,200	10,000
TOTAL	--	--	484,780

1/ Price base: 1968

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TABLE 2 - ESTIMATED STRUCTURAL COST DISTRIBUTION

Kahaluu Watershed, Hawaii

(Dollars)[1]

Item	Installation Cost P. L. 566 Funds				Installation Cost - Other Funds				Total Installation Cost
	Construction	Engineering	Land Rights	Total PL-566	Construction	Engineering	Land Rights	Total Other	
A-1 Channel	814,740	97,770	-	912,510	-	-	59,180	59,180	971,690
KA-2 Channel	566,860	68,020	-	634,880	-	-	35,750	35,750	670,630
W-1 Channel	430,620	51,760	-	482,380	-	-	45,630	45,630	528,010
W-2 Channel	218,520	26,220	-	244,740	-	-	30,390	30,390	275,130
NW Channel	242,020	29,040	-	271,060	-	-	101,220	101,220	372,280
KA-2 Debris Basin	61,730	7,410	-	69,140	-	-	23,110	23,110	92,250
W-1 Debris Basin	25,730	3,090	-	28,820	-	-	5,820	5,820	34,640
KA-1 SAF Basin	242,670	29,120	-	271,790	-	-	7,870	7,870	279,660
W-1 SAF Basin	115,970	13,920	-	129,890	-	-	7,890	7,890	137,780
Multi-purpose Channel System	883,740	106,050	17,770[3]	1,007,560	29,840	-	1,269,560	1,299,400	2,306,960
Recreational Facilities	138,330	-	177,700	316,030	138,330	27,670	179,290	345,290	661,320
Subtotal	3,740,930	432,400	195,470	4,368,800	168,170	27,670	1,765,710	1,961,550	6,330,350
Project Administration	-	-	-	374,090	-	-	-	236,350	610,440
GRAND TOTAL	3,740,930	432,400	195,470	4,742,890	168,170	27,670	1,765,710[2]	2,197,900	6,940,790

1/ Price base: 1968

2/ Includes $55,000 for relocation of 30" water main, $34,000 for road relocation, $49,000 for house relocations, and $12,190 for legal and other fees for land acquisition.

3/ Includes $5,000 for house relocations.

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TABLE 2A - COST ALLOCATION AND COST SHARING SUMMARY

Kahaluu Watershed, Hawaii

(Dollars)[1/]

Item	COST ALLOCATION			COST SHARING					
	Purpose			P. L. 566			Other		
	Flood Prevention	Recreation	Total	Flood Prevention	Recreation	Total	Flood Prevention	Recreation	Total
Concrete Channels, Debris Basins and SAF Basins	3,362,070	--	3,362,070	3,045,210	--	3,045,210	316,860	--	316,860
Multi-purpose Channel System	2,207,760	99,200	2,306,960	956,370	51,190	1,007,560	1,251,390	48,010	1,299,400
Recreational Facilities	--	661,320	661,320	--	316,030	316,030	--	345,290	345,290
GRAND TOTAL	5,569,830	760,520	6,330,350	4,001,580	367,220	4,368,800	1,568,250	393,300	1,961,550

1/ Price base: 1968 July 1969

TABLE 2B - RECREATIONAL FACILITIES

ESTIMATED CONSTRUCTION COSTS

Kahaluu Watershed, Hawaii

(Dollars)[1/]

Item	Number	Estimated Unit Cost [1/]	Total Construction Cost
Clearing	21.7 Acres	300	6,510
Roadway	2,200 L.F.	20	44,000
Pedestrian Trail	3,000 L.F.	2	6,000
Parking Area	100 Stalls	200	20,000
Comfort Stations	2 Each	20,000	40,000
Picnic Area	100 Sites	300	30,000
Boat Ramp	1 Each	10,000	10.000
Landscaping	20 Acres	4,000	80,000
Utilities	--	15,000	15,000
	Construction Estimate		251,510
	Contingencies		25,150
	Total Construction Cost		276,660

1/ Price base: 1968

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TABLE 3 - STRUCTURE DATA

DEBRIS BASIN AND INLET STRUCTURE

Kahaluu Watershed, Hawaii

Item	Unit	Structure Number		Total
		KA-2 Debris Basin	W-1 Debris Basin	
Drainage Area	Sq. Mi.	1.34	1.81	3.15
Debris Basin Storage	Cu. Yds.	1,200	1,700	2,900
Debris Surface Area	Ac.	0.27	0.26	3.2
Volume of Excavation	Cu. Yds.	34,410	4,380	38,790
Inlet Structure				
Top Elevation	Ft.	94.91	60.40	--
Crest Elevation	Ft.	73.71	45.40	--
Bottom Width	Ft.	25	50	--
Design Flow	cfs	7,530	8,830	--

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TABLE 3A - STRUCTURE DATA

CHANNELS

Kahaluu Watershed, Hawaii

Channel	Station	Drainage Area Sq. Mi.	Capacity cfs		Water Surface Elev. 1/	Hydraulic Gradient (ft./ft.)	Channel Dimensions			Velocity fps	Total Excavation Cu.Yds.	Type of Improvement 3/
			Req'd	Design			Bottom (ft.)	Depth (ft.)	Side Slopes			
A-1 4/	0+10	1.32	4,860	4,860	58.3	0.0100	30	7.0	1:1	18.8		L
	0+70	1.32	4,860	4,860	52.7	0.0091	30	6.1	0	31.8		L
	17+58	1.55	5,710	5,710	38.2	0.0136	30	8.9	0	28.1		L
	22+88	2.37	7,410	8,610	31.5	0.0074	40	7.9	0	32.6		L
	45+09	3.92	12,450	13,160	14.6	0.0066	65	8.9	0	27.4		L
	46+45	3.92	12,450	13,160	12.8		65	8.2	0	33.7	83,320	SAF
KA-1	48+63	3.92	12,450	13,160	3.6		150	18.5	0	6.9		SAF
Lagoon	49+30	3.92	12,450	13,160	3.6	0.0015	280 2/	20.2	3:1	3.7		U
	68+50	4.19	13,160	13,160	0.7	0.0003	300 2/	14.0	3:1	4.8		U
	71+58	7.67	19,940	19,940	0.6	0.0004	280	15.8	1:1	6.6		SR
	79+25	7.67	19,940	19,940	0.3		280	12.3	1:1	6.5	593,960	SR
KA-2	0+00	1.08	4,630	5,760	84.9	0.0909	25	21.8	0	19.5		L
	36+60	1.34	5,760	5,760	12.9	0.0183	25	8.9	0	36.6	43,620	L
W-1	2+60	1.63	5,100	5,400	52.5	0.0208	50	8.7	0	15.2		L
	5+10	1.63	5,100	5,400	47.3	0.0202	25	11.1	0	23.2		L
	26+17	2.41	6,900	6,900	10.6	0.0526	45	10.0	0	22.0		L
	27+17	2.41	6,900	6,900	8.7		45	7.3	0	25.5		SAF
	28+58	2.41	6,900	6,900	1.1		100	16.9	0	6.3	42,060	SAF

(Continued on following page.)

TABLE 3A - STRUCTURE DATA (Cont)

CHANNELS

Kahaluu Watershed, Hawaii

Channel	Station	Drainage Area Sq. Mi.	Capacity cfs		Water Surface Elev. 1/	Hydraulic Gradient (ft./ft.)	Channel Dimensions			Velocity fps	Total Excavation Cu.Yds.	Type of Improvement 3/
			Req'd	Design			Bottom (ft.)	Depth (ft.)	Side Slopes			
W-2	1+13	0.49	2,150	2,380	21.9	0.0143	20	11.4	0	15.7		L
	17+40	0.61	2,380	2,380	11.0	0.0063	20	8.0	0	17.8		L
											16,770	
NW	1+89	0.38	1,820	1,820	11.4	0.0100	26	5.4	0			L
	4+20	0.38	1,820	1,820	9.1	0.0533	26	4.8	0	14.6		L
	4+50	0.38	1,820	1,820	7.5	0.0026	32	3.3	0	17.2		L
	23+50	0.55	2,450	2,450	2.6	0.0026	32	5.0	0	15.3		L
											13,600	

NOTE: "n" value for all concrete-lined channel is 0.014 and for KA-1 Lagoon is 0.03.

1/ Water surface elevations for the Lagoon were computed beginning at mean lower low sea level at the outlet.

2/ Bottom widths vary throughout the Lagoon.

3/ SR - Stone revetment
SAF - Stilling basin
U - Unlined Channel
L - Lined Channel

4/ Construction of channel improvements from Station 17+58 to Station 22+88 will be part of the Kahekili Highway construction contract (see fig. 4).

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TABLE 4 - ANNUAL COST

Kahaluu Watershed, Hawaii

(Dollars)[1/]

Evaluation Unit	Amortization of Installation Cost [2/]	Operation and Maintenance Cost	Total
Flood Control and Recreation Measures	296,010	61,900 [3/]	357,910
Project Administration	28,540	--	28,540
GRAND TOTAL	324,550	61,900	386,450

1/ Price base: Installation 1968, O&M Adjusted Normalized.
2/ 100 years at 4-5/8 percent interest.
3/ Includes $30,800 for operations, maintenance, and replacement for the recreational development.

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TABLE 5 - ESTIMATED AVERAGE ANNUAL FLOOD DAMAGE REDUCTION BENEFITS

Kahaluu Watershed, Hawaii

(Dollars)[1/]

Item	Estimated Average Annual Damage		Damage Reduction Benefit
	Without Project	With Project	
Floodwater			
Crop and Pasture	8,630	0	8,630
Other Agricultural	3,610	0	3,610
Nonagricultural:			
Resort	2,250	0	2,250
Industrial	7,490	0	7,490
Commercial	40,820	0	40,820
Residential	74,430	0	74,430
Public Agencies and Utilities	57,590	970	56,620
Subtotal	194,820	970	193,850
Sediment			
Agricultural	5,590	0	5,590
Nonagricultural:			
Commercial	21,780	0	21,780
Residential	16,190	460	15,730
Other	5,190	0	5,190
Subtotal	48,750	460	48,290
Erosion			
Flood Plain Scour	53,490	0	53,490
Streambank	3,200	0	3,200
Subtotal	56,690	0	56,690
Indirect	47,290	140	47,150
TOTAL	347,550	1,570	345,980

1/ Adjusted normalized price base.
Damages and benefits will accrue from floods of greater magnitude than 1% frequency, but were not evaluated.

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TABLE 6 - COMPARISON OF BENEFITS AND COSTS FOR STRUCTURAL MEASURES

Kahaluu Watershed, Hawaii

(Dollars)

Evaluation Unit	AVERAGE ANNUAL BENEFITS 1/			Total	Average Annual Cost 3/	Benefit Cost Ratio
	Damage Reduction	Recreation	Secondary			
Flood Control and Recreation Measures	331,850	144,810	39,730	516,390	357,910	1.4:1.0
Project Administration					28,540	
GRAND TOTAL	331,850 2/	144,810	39,730	516,390	386,450	1.3:1.0

1/ Adjusted normalized price base.
2/ In addition, it is estimated that land treatment measures will provide floodwater, sediment and erosion damage reduction benefits of $14,130 annually.
3/ From Table 4.

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TABLE 7 - CONSTRUCTION UNITS

Kahaluu Watershed, Hawaii

(Dollars)

Measures in Construction Unit	Annual Benefit 1/	Annual Cost 2/
Flood Control and Recreation Measures	516,390	357,910

1/ Adjusted normalized price base.
2/ From Table 4.

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INVESTIGATIONS AND ANALYSES

Project Formulation

Land Treatment Measures

Land treatment measures to be applied in the watershed area are the needed treatment measures as determined by the Soil Conservation Service and the local sponsors. Soil survey maps prepared by SCS form the base on which the treatment needs were determined. These needs conform to the standards and specifications for practices as set forth in the Technical Guide prepared for use in the Windward Oahu Soil and Water Conservation District.

The amount and extent of the treatment program were determined from on-site investigations, aerial photos and tax-key maps. Costs were determined from price studies and experience in Hawaii.

Structural Measures

Floodwater retarding reservoirs for controlling flood flows were investigated. Lack of feasible sites, due mainly to the steep terrain, eliminated possibilities for retention storage. Channel improvements were determined to be most feasible measures for flood prevention in the flood plain.

Channel improvement designs were generally of the type used in other Public Law 566 projects in Hawaii. Alignments of needed improvements followed the existing drainageways except where other alignments allowed more economical alternatives. Various channel types were studied for each reach, including vegetated trapezoidal channels and reinforced concrete lined channels of rectangular and trapezoidal sections. The alternative with the most economical equivalent annual cost was always used. In general, channels located above the flood plain were on steeper slopes requiring lined sections. In the flood plain, high land rights costs usually favored the use of narrower lined sections.

The extent of structural measures planned was based on a benefit to cost analysis for each reach. All reaches in the lower flood plain were found to be economically feasible. These were evaluated as one unit. A portion of the upper Kahaluu Stream was also found to be feasible. All the remaining reaches studied were not found to be economically feasible.

The design of debris basins, SAF energy-dissipating structures, and junction and transition structures conform to current engineering criteria developed for Public Law 566 works of improvement.

The basic facility needs and designs for the recreational development were determined by the City and County of Honolulu Parks and Recreation Department. This Department has the facilities and experience to prepare the design and specifications for the works during the operation phase.

Hydrologic Investigations and Analyses

Basic Data

Water-stage recorders for measuring streamflows and rain recording gages are located on the Kahaluu and Waihee streams. These recorders are located near the headwaters of the streams and only record a small percentage of the runoff from the subwatersheds. A crest-stage station is located on Ahuimanu Stream and records a larger percentage of the subwatershed. The period of record for the Kahaluu Stream gage is 32 years, for the Waihee Stream gage is 31 years and for the Ahuimanu Stream gage is 6 years. Storm hydrographs from the two water-stage recorders were made available by the U.S. Geological Survey. These records, together with rainfall data, soil survey maps, soils descriptions, and land use maps were used in studying hydrologic characteristics of the area.

Flood Volume

Volume-duration-frequency studies were based on the runoff data from Kahaluu and Waihee Streams. The frequency of return for given volumes of runoff was determined from these data. The recorded volumes of runoff

for given frequencies of return were then compared with calculated volumes of runoff from this area for storms of the same frequencies. Runoff volumes were calculated using procedures contained in the Soil Conservation Service's National Engineering Handbook, Section 4 - Hydrology, Chapters 9 and 10. Rainfall frequency, duration and intensity were read from the U.S. Weather Bureau publication, "Rainfall Frequency Atlas of the Hawaiian Islands," Technical Papers No. 43 and No. 51.

Comparison showed the recorded streamflow volume was a little lower than the calculated volume. Most of the difference can be attributed to a water supply diversion located upstream from the water-stage recorder.

This comparison showed that the method for calculating runoff is reliable. Because the recorded streamflow data are limited and only pertain to a small part of the watershed, it was necessary to rely on calculated runoff data for the entire watershed.

Flood Peak Flows

Peak runoff rates for the one percent storm event were used for the design capacities of the proposed waterways. A storm period of six hours was determined to be the critical duration. The flow rates were derived from synthetic hydrographs developed by the method contained in Chapter 21 of the Hydrology Handbook. An antecedent moisture condition III was used in all runoff determinations.

Times of concentration were obtained using Kirpich's method. Adjustments were made for waterfalls and the estimated times were found to be reasonable when expressed in velocities of travel. This method is compatible with that used by the Department of Public Works, City and County of Honolulu. A check on this method of peak flow determinations was made for the small watershed above the Kahaluu Stream gage. Using the historical record of peak flows, a frequency plot was made using the method in Chapter 18 of the Hydrology Handbook. The peak flow for the 100-year storm was derived from the plot. This flow compared favorably with the 100-year peak flow derived by the synthetic method.

The design flows were routed through channel reaches. It was found, however, the hydrographs were not

appreciably modified. This was due to the high channel velocities and relatively short reaches of channels. Inflow hydrographs were thus added at the channel junctions with consideration for offset due to travel times.

Flood frequencies for recent flood events were published by the U.S.G.S. in their Hydrologic Investigations Atlas HA-239 (1966). These frequencies were used in the economic investigations and analyses. To complete the damage-frequency curves for the economic analyses, the estimated one-, 10-, and 20-percent chance flood flows were routed through the flood plain.

Engineering Investigations and Analyses

Surveys

Topographic surveys were made by the Department of Land and Natural Resources of the State of Hawaii. Maps were prepared to a scale of one inch equals fifty feet with two-foot contour intervals. Photo mosaics with a scale of one inch equals five hundred feet were used to delineate sediment source areas. Eight-inch by eight-inch stereo-pairs and one inch equals three hundred feet aerial photographs were also used in preliminary design and land use determinations.

Design

The channel alignments follow existing streams as much as possible in order to reduce land acquisition and construction cost. The concrete-lined channel designs are of rectangular cross sections. Flow velocities in the lined channels are supercritical.

Flows entering the lagoon will be directed through SAF (St. Anthony Falls) energy dissipating basins. Design for the SAF basins was based on "SAF Outlets" in the NEH 14, Chute Spillways. Channel hydraulic design was based on the NEH 5, Hydraulics and SCS Engineering Design Standards - Far West States.

A Manning's "n" value of 0.014 was used for the concrete lining. Water surface profiles for the concrete channels were run from the inlet downstream beginning at critical depth. Water surface profiles for the lagoon

were run from the outlet beginning at both mean lower low tide and mean higher high tide. The SAF basins were designed using the tail-water depth at mean lower low tide. The profile at mean higher high tide determined the minimum freeboard for the lagoon and the additional height of the SAF basin sidewalls. The freeboard was determined according to the criteria in the Engineering Design Standards - Far West States.

The multi-purpose channel system (lagoon) will be in earth cut with 3:1 side slopes. The slopes will be grassed above mean sea level and rock riprap installed from mean sea level to maximum low tide level. A salt-resistant grass, Paspalum hydrophilum, will be used. This grass is presently growing on the banks of the Oneawa channel at Kailua, Oahu, and is subject to tidal submergence of more than a foot. Grass stock will be developed at the SCS Plant Materials Center at Wailuku, Maui, to assure availability during installation.

Logs and soil tests of State Highway borings adjacent to the KA-1 Lagoon were analyzed. Maximum velocities for the design flow were determined using criteria in Chapter 6 of Technical Release No. 25 of the Soil Conservation Service.

A Manning's "n" value of 0.03 was determined by criteria described in NEH 5, Supplement B.

A 280-foot bottom width outlet into Kaneohe Bay was chosen due to the velocity limitation. A concrete contraction under the Kamehameha Highway was considered in order to save on bridge costs, but this alternative proved to be more costly. The outlet section was designed with an unlined invert and armor stone revetment.

Cost estimates were derived from experience on similar projects. Contingencies for unforeseen additional costs were covered by the addition of 15 percent of these costs to the engineering estimate.

Geologic Investigations and Analyses

Sedimentation

A survey of existing sedimentation conditions of each stream was made. Debris basins were determined to be needed at two of the channel inlets showing high cobble

and boulder movements. Basin capacities were developed from projected yields at the inlets. (See Table 3.) Because of topographic limitations, capacities were designed to control the projected yields for events greater than the design storm. Strict maintenance of the basins will be required with annual and post storm inspections to determine maintenance needs.

Channel Sites

The State Highway borings adjacent to the sites for the KA-1 Lagoon and the lower section of the A-1 channel were studied. The soil tests showed the foundation material to be mostly clayey sand (SC) and elastic silt (MH) interspersed with gravel and cobbles. Plasticity indices and unconfined compression shear tests data show that gravel blankets will be needed under the concrete channel sections to insure stability and allow ground water to filter into the channels through weep holes.

Excavations and channel construction works near the proposed channel sites were visually inspected. No foundation problems were observed in the installation of the concrete channels or other improvements.

Economic Investigations and Analyses

General

Flood damages were evaluated to determine benefits obtained by application of land treatment measures and the installation of structural works of improvement in the watershed. This required an analysis of how land use on the flood plain will change during the project life and evaluating its effect on damages expected under these future uses. Investigations showed the relationship of flooding elements such as depth, area, seasonal occurrence, location and dollar values.

Once the total damages to agricultural and other cultural features were derived, the estimated benefits that would be obtained from the project structural measures were computed. Residual damages that would occur with the project installed were considered in this analysis. The recreational development was evaluated with regard to benefits and costs. Most of the data needed for projecting potential use were furnished by the Honolulu Parks and Recreation Department.

Damage Appraisal

In appraising damages for the economic investigations, it was necessary to obtain data covering the entire flood plain. The appropriate stream and flood plain reaches were identified to provide a means for:

1. Identifying and locating damages and other benefits.

2. Relating damage reductions or other benefits to works of improvement.

3. Bringing the evaluation of hydrologic and economic data together for determination of stage-area-damage relationships.

Soil Conservation Service personnel conducted four post-flood damage surveys during the period of 1963-1966.

The appraisal of damages in the agricultural area was based on losses to agricultural property, including private roads. Crop damage was determined by estimating loss in net income for the various crops affected, using

cost of production studies developed by the University of Hawaii. Data on yields and prices received by farmers for each crop were obtained from the Hawaii Crop and Livestock Reporting Service and from interviewing farm operators in the watershed.

Damages to nonagricultural property such as residential, commercial and industrial, were also determined. Information on damages to highways, bridges, and utilities was obtained by interviewing public agencies and utility companies. Commercial and industrial firms were so varied in their equipment, inventory and susceptibility to damage that a complete inventory of damages was necessary in order to obtain accurate records.

Existing Conditions

In order to evaluate past damages under existing conditions, three storms adequately dispersed were selected. The storms of April 1963, May 1965, and November 1965 were evaluated in terms of damages, frequencies, and classified according to types of damages, i.e., sediment, erosion, and floodwater. Further refinement of this data was obtained by categorizing damages into residential, commercial, agricultural and public agency.

The damage information was supplemented by analysis of other isolated damages within the flood plain. These included incidents which demonstrated an accumulation of damages that peak out during major storms on the lower reaches of the watershed, e.g., streambank erosion of commercially-zoned land. Also included in the evaluation is the calculation of average annual expenditure within the flood plain by public agencies. All damage figures were normalized by using the U.S. Department of Commerce Construction Costs Composite Index (1957-59 = 100).

Estimates of the average annual damage under existing conditions were then developed through damage-frequency curves as presented in Chapter 3 of the Soil Conservation Service Economics Guide.

Projected Conditions

Before evaluating the projected average annual damage for each type of development in the flood plain, the growth rate of these developments had to be established.

Projections were largely based on information obtained from the Department of Planning, City and County of Honolulu; the Department of Health, State of Hawaii; the Department of Economic Planning and Development, State of Hawaii and private developers.

The present pattern of land use and zoning was also considered in the analysis. It was found that although some of the land zoned residential was still in agriculture, these were principally used as low-yield pastureland.

Another factor considered in the projections was actual area encompassed by the different floods for several frequencies. A modified method of urban damage analysis, based on investigations for the Escondido Creek (Calif.) Watershed project, was used in the damage analysis. The flood depths and extent of flooding for the 1, 10, and 20 percent events were determined by the hydrologist.

All damage curves with the exception of the resort damage curve were derived from actual flood damage data in the watershed. Using a least square linear regression analysis, the damage curves for residential and commercial developments were derived. Data for resort damages were not available in the flood plain. The damage curve obtained in the Kona Watershed was used because of its similarity in terms of structures, fixtures, etc. Public agency damage was projected on the basis of population growth in the watershed.

Residential Property Analysis. The Kahaluu area has three distinct types of homes each having its own type of problems. To obtain a damageable value per acre on a projected basis, factors such as rate of development, population growth, availability of other land areas where urbanization could take place, supporting infrastructures and engineering costs had to be considered.

Data was obtained from several subdivisions on Oahu to arrive at reliable construction cost estimates. A sample area selected in the watershed gave an indication of the existing density. Before any reliable projection of residential area could be made, the number and size of residential lots were determined.

Data from the residential schedules were assembled and formulated into a stage-damage curve. A comparison of this curve with that published for mainland United States indicated that Kahaluu damages tended to be higher. This was probably due to the higher flood-flow velocities which often sweep through the Kahaluu residential areas. A linear regression analysis was used to determine the actual slope of the damage curve. The curves were checked for reliability by a computer program, which also calculated partial correlation coefficients for total damage and each of the three most significant damage factors. The three most significant damage factors considered in the study were cost of structures and contents, inside depth of water and height of first floor from the ground.

Commercial Property Analysis. The first step in the commercial property analysis was to determine the type of development existing and projected for the future. Each commercial area has an average pattern of development, that is, so much area is devoted to streets, parking area, and to the business structure itself.

The next step was to analyze the pattern and to determine a monetary value per acre of commercial land. This value is derived from construction costs of the building, its fixtures, the parking lot and the stocks and supplies required by a particular business. The first three are derived by working with construction costs obtained from local construction firms.

The most important analysis required to obtain a damageable value per foot was to determine the value of commercial inventories. This was difficult because of the many different types of stores, each with a different value on its stocks and properties. This was accomplished on a "weighing process" by dividing the businesses into 12 categories and obtaining the square foot value of inventory for each. The values were then averaged by the proportion each type of business is of the whole. Division of all commercial business was obtained from the following sources:

1. 1963 Census of Business - Hawaii, U.S. Department of Commerce, 1966.

2. Expenses in Retail Business, National Cash Register.

3. Department of Taxation, State of Hawaii.

Flood damages in commercial areas were predicted on the total value of structural improvements, contents and depths of inundation. Damages were obtained from depth-damage curves derived through linear regression.

Industrial Property Analysis. The same general method of analysis was used for industrial property as for commercial developments. Development patterns, values for structures, fixtures and contents were established to arrive at the per acre value of industrial property. Depth-damage curves were then used to derive damages.

Resort Property Analysis. There are 233 acres in the watershed zoned for resort use. Approximately 45 acres of this is a defunct commercial fishpond the flood plain. Damaged during the flood of May 1965, the area is now being planned for resort use. The projection of damages to the proposed resort development involved using the resort damage curve derived for the Kona watershed project. Information from the developers, including the preliminary site plan, facilitated the analysis.

Analysis of Public Agency Expenditure. Flooding in the watershed has involved a number of agencies in emergency rescue and evacuation operations. Actual expenditures by the public agencies were obtained from interviews initiated after the floods. For projected conditions, public agency expenditures were assumed to have a direct relationship with the projected population growth in the watershed.

Indirect Damages

Investigations of the economic effects resulting from floodflows indicated considerable indirect damage resulted from the interruption of normal business activities and the loss of production time for a period following each flood. Indirect damages were estimated as a percentage of direct damages as follows: commercial and agricultural damages, 15 percent; residential, 10 percent; and public utilities, 20 percent.

Recreation Benefit Analysis

The analysis for recreation benefits was largely based on data furnished by the Honolulu Department of Parks and Recreation. The entire island of Oahu is within the zone of influence of the Kahaluu recreation area. All population centers in the City and County of Honolulu are within a 30-mile radius.

The average annual rate of 95,000 visitor-days reflects the proximity to large urban populations. This rate reflects the lack of competing facilities and the unlimited number of use-days allowed by the equable climatic conditions. Each visitor day was valued at $1.25. An additional 120,000 mainland visitors are annually expected to briefly stop at the park development during bus tours of the island. The value of this visitor-day was considered to be $.25.

Secondary Benefit Analysis

Secondary benefits from a national viewpoint were not considered in the economic evaluation. Benefits were limited to those project goods and services occurring within the watershed that were readily identifiable.

The secondary benefits "stemming from" the project were evaluated at ten percent of the direct primary benefits. Direct primary benefits included in the computation are damage reduction benefits exclusive of indirect benefits and erosion damage reduction benefits. Other secondary benefits in this category were not evaluated. The value of local secondary benefits "induced by" the project were estimated to equal ten percent of the increased costs that will be incurred in connection with project costs necessary to achieve certain primary project benefits, e.g., operation and maintenance of basic recreational facilities.

The procedures in Chapter 11 of the SCS Economics Guide were used for determining secondary benefits.

LEGEND

- Nearly level to gently sloping, poorly drained bottomland soils. Typical series, Hanalei and Pearl Harbor.
- Very deep, well-drained, permeable soils on alluvial fans and terraces. Typical series, Waikane and Lolekaa.
- Deep and very deep, well-drained, dark reddish-brown residual upland soils. Typical series, Alaeloa.
- Precipitous cliffs consisting of bare rock and extremely shallow soils

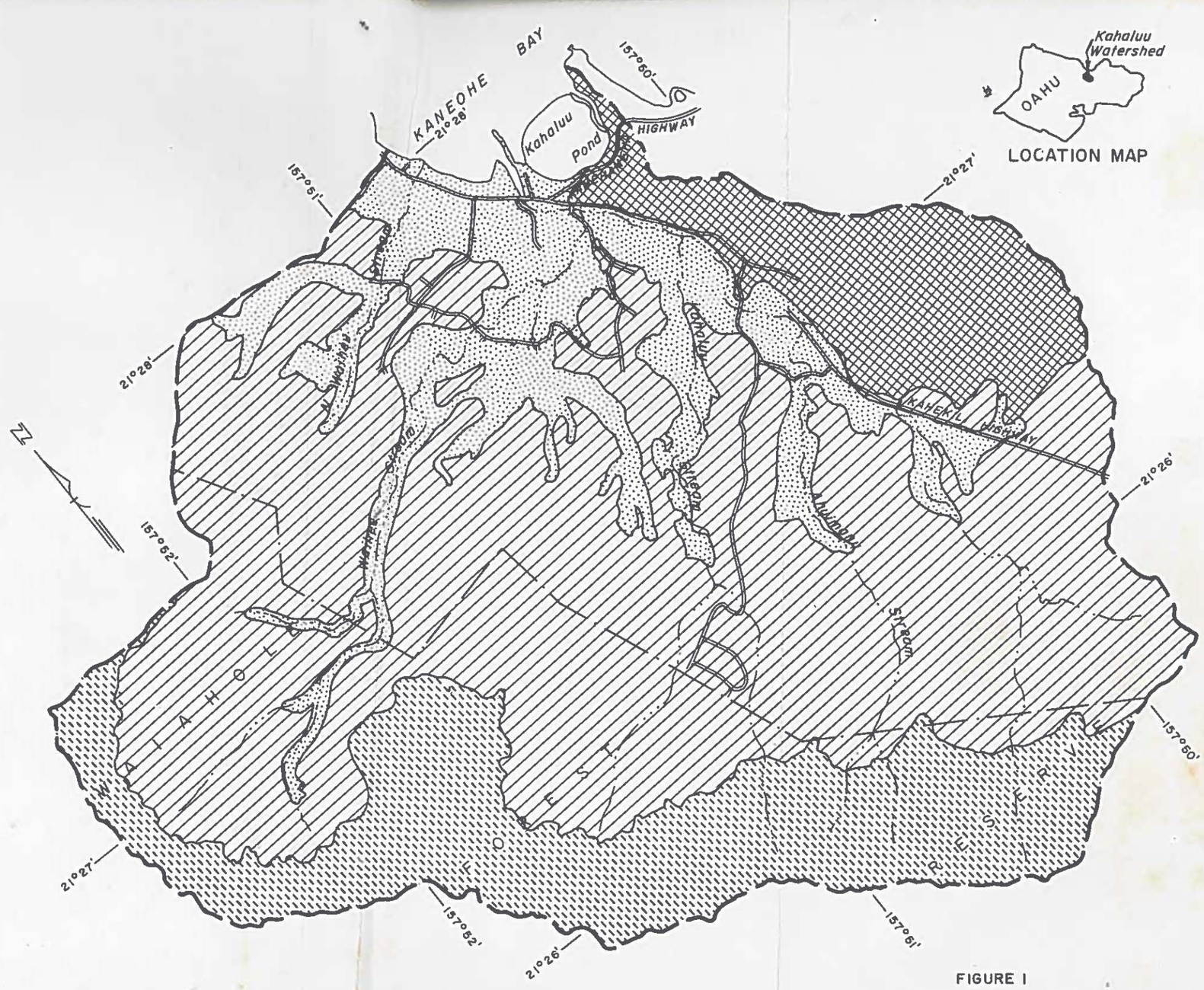


FIGURE 1
GENERAL SOIL MAP
KAHALUU WATERSHED
ISLAND OF OAHU, HAWAII

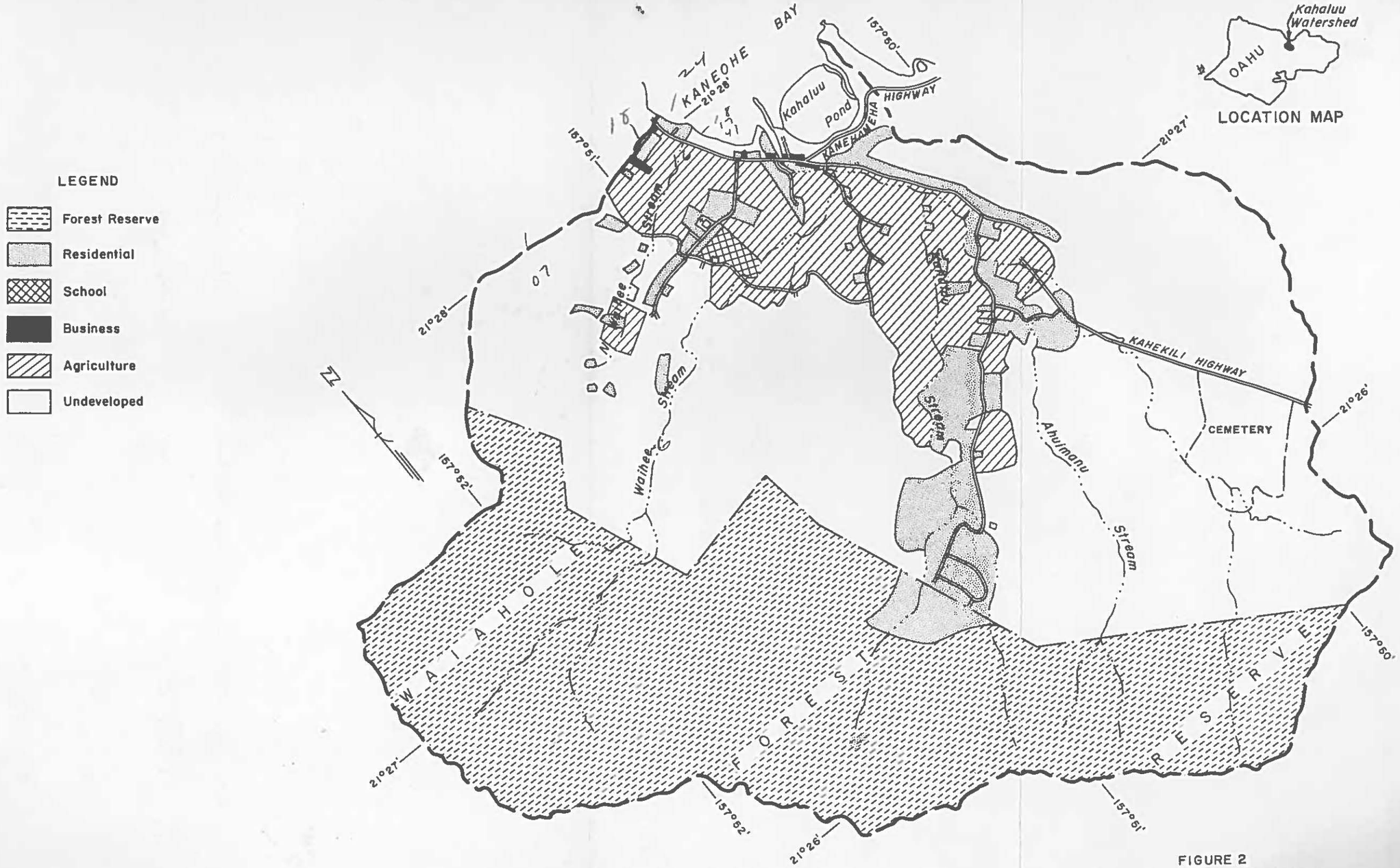
JULY 1969

1000 0 1000 2000 3000
SCALE IN FEET
SCALE 1:24,000

Prepared by HYTL, 1-68

U. S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND, OREG. 1969

M 7-N-21301-1



Updated from City and County of Honolulu
City Planning Commission Map, August 1960

FIGURE 2
EXISTING LAND USE MAP
KAHALUU WATERSHED
ISLAND OF OAHU, HAWAII

JULY 1969

1000 0 1000 2000 3000
SCALE IN FEET
SCALE 1:24,000

M7-N-21301-1

U. S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND, OREG. 1969

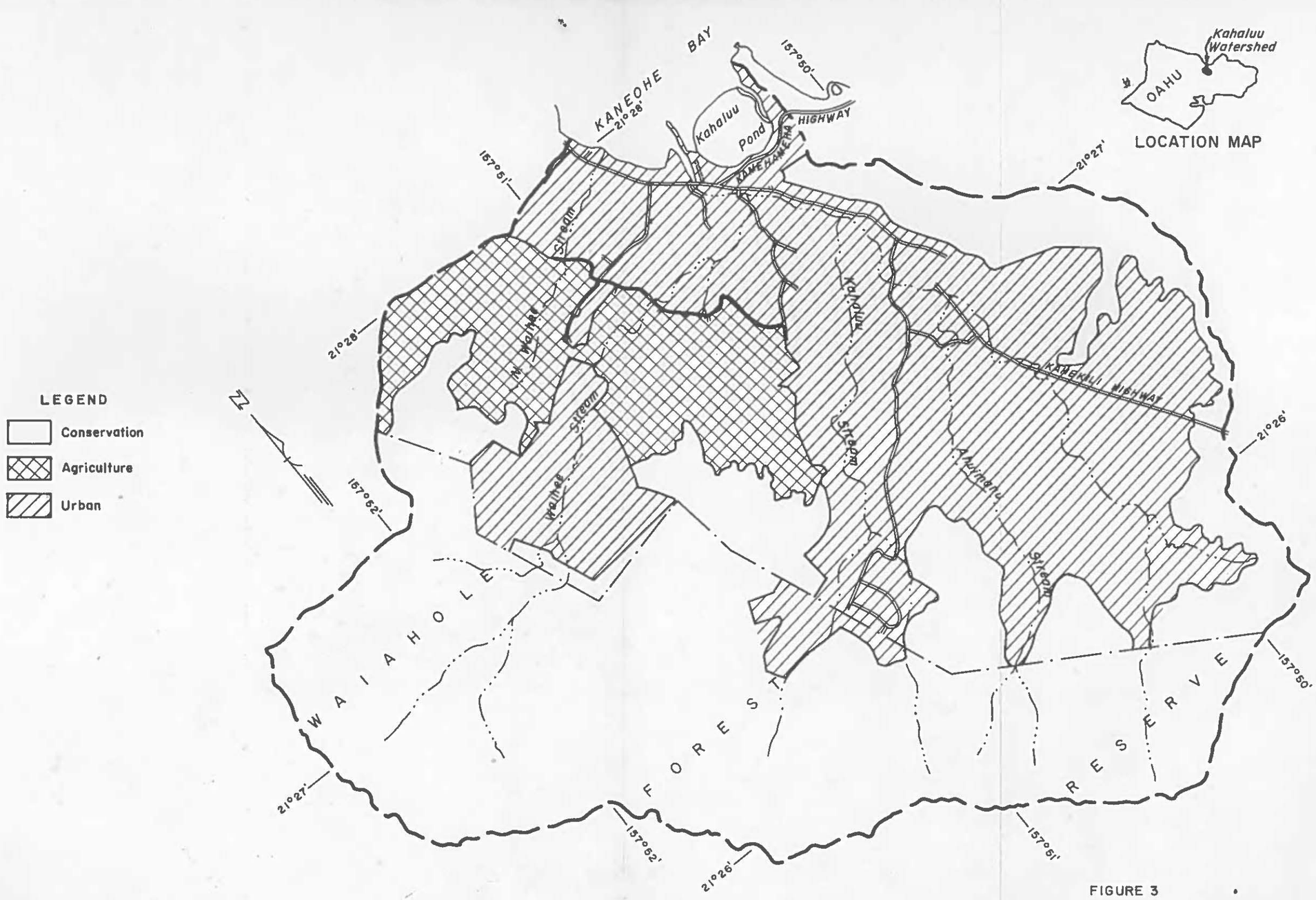


FIGURE 3

LAND USE DISTRICT BOUNDARIES

KAHALUU WATERSHED

ISLAND OF OAHU, HAWAII

MARCH 1969

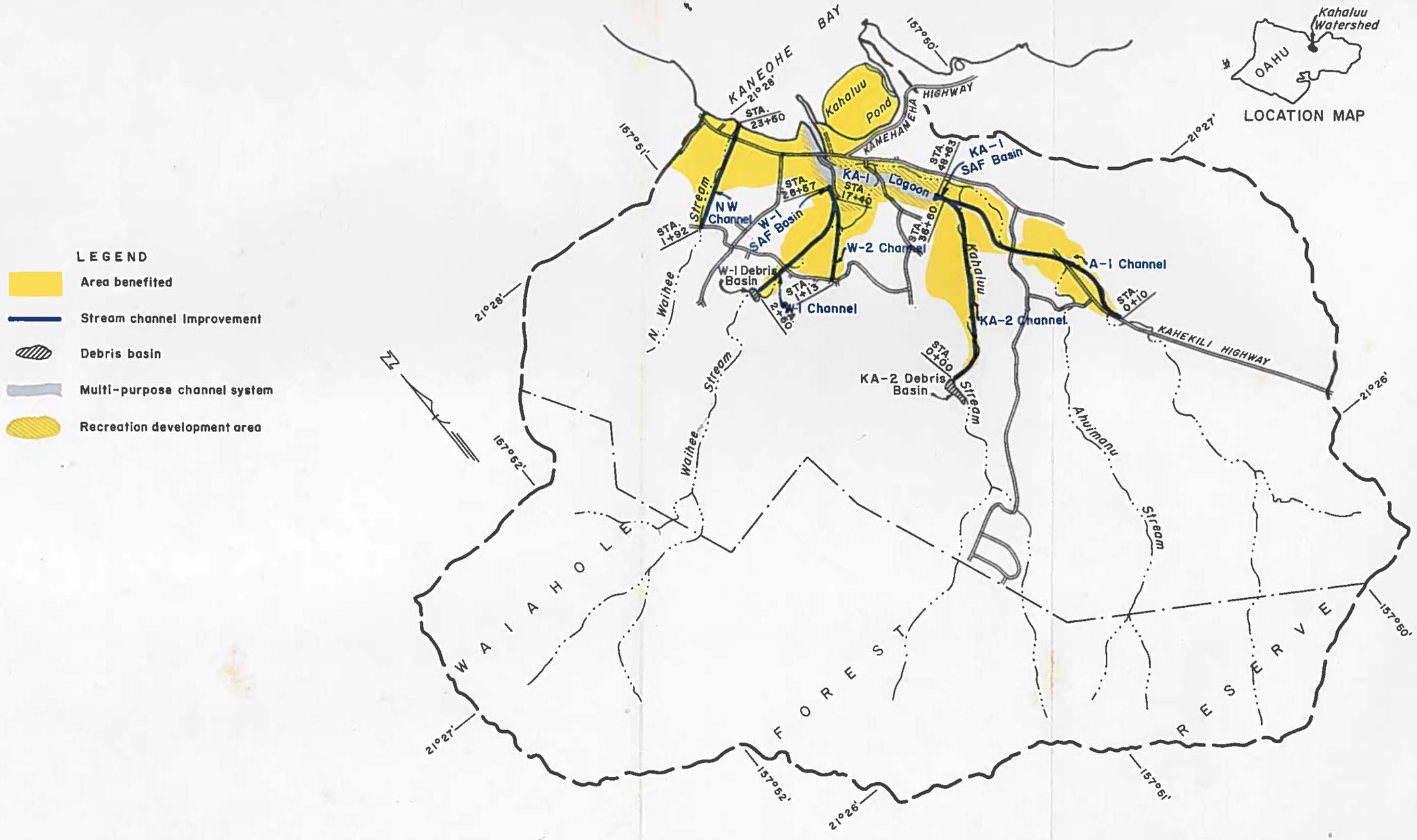
1000 0 1000 2000 3000

SCALE IN FEET

SCALE 1:24,000

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND, OREG. 1969

M7-N-21301-3



PROJECT MAP
KAHALUU WATERSHED
ISLAND OF OAHU, HAWAII

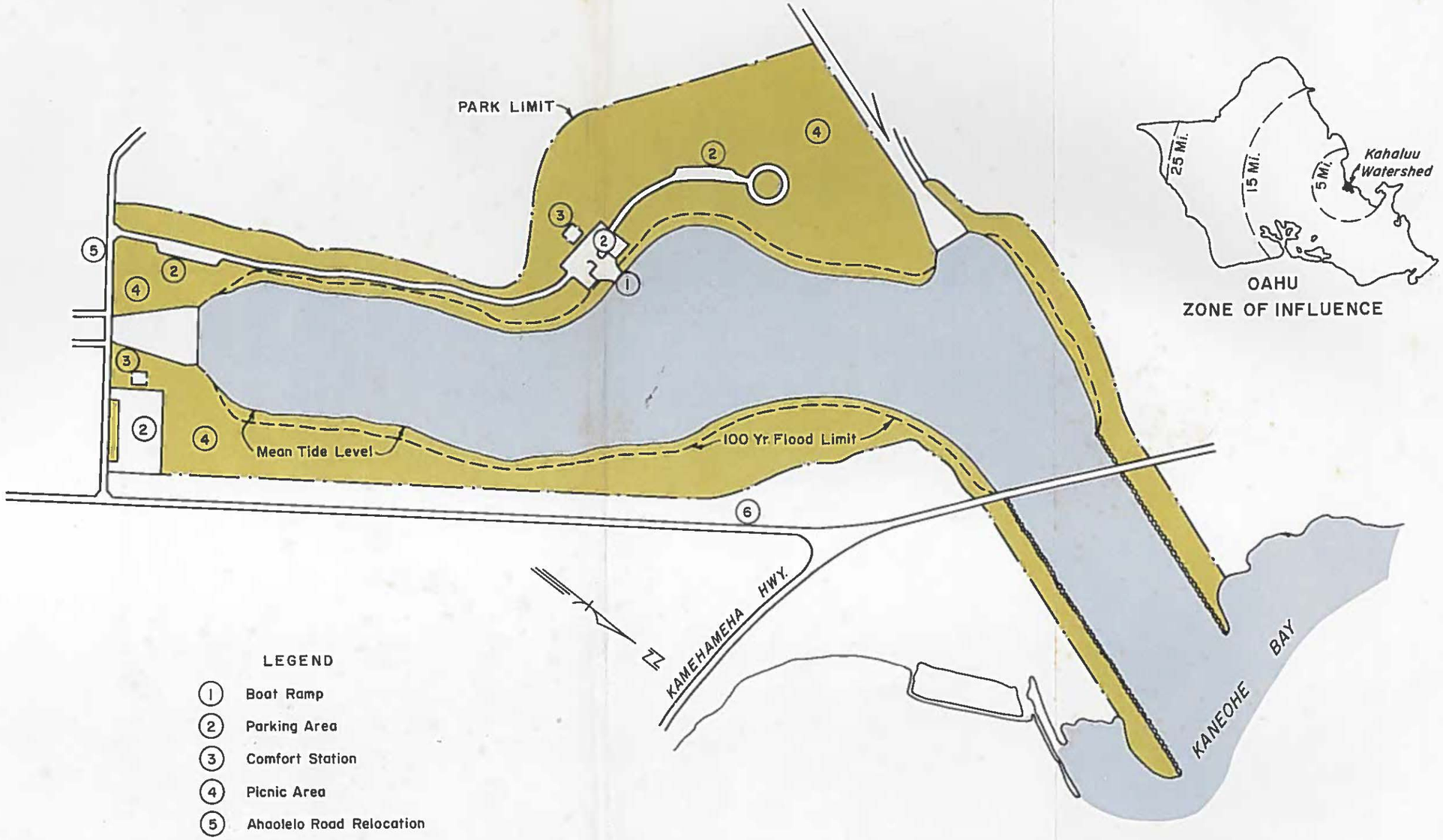
JULY 1969

1000 0 1000 2000 3000
SCALE IN FEET
SCALE 1:24,000

Prepared by S.L.W., 5-69

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND, OREG. 1969

M7-N-21301-10



LEGEND

1. Boat Ramp
2. Parking Area
3. Comfort Station
4. Picnic Area
5. Ahaolelo Road Relocation
6. Kahekili Highway Extension

300 0 300 600
SCALE IN FEET
SCALE 1 : 3600

FIGURE 9
WORK PLAN

KA-I LAGOON AND PARK RECREATION DEVELOPMENT

KAHALUU WATERSHED
ISLAND OF OAHU, HAWAII

PRELIMINARY PLANS

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE
Prepared by Dept. of Parks and Recreation, City and County of Honolulu
Date 5-69 Drwg. No. M7-N-21301-9

USDA-SCS-PORTLAND, OREG. 1969

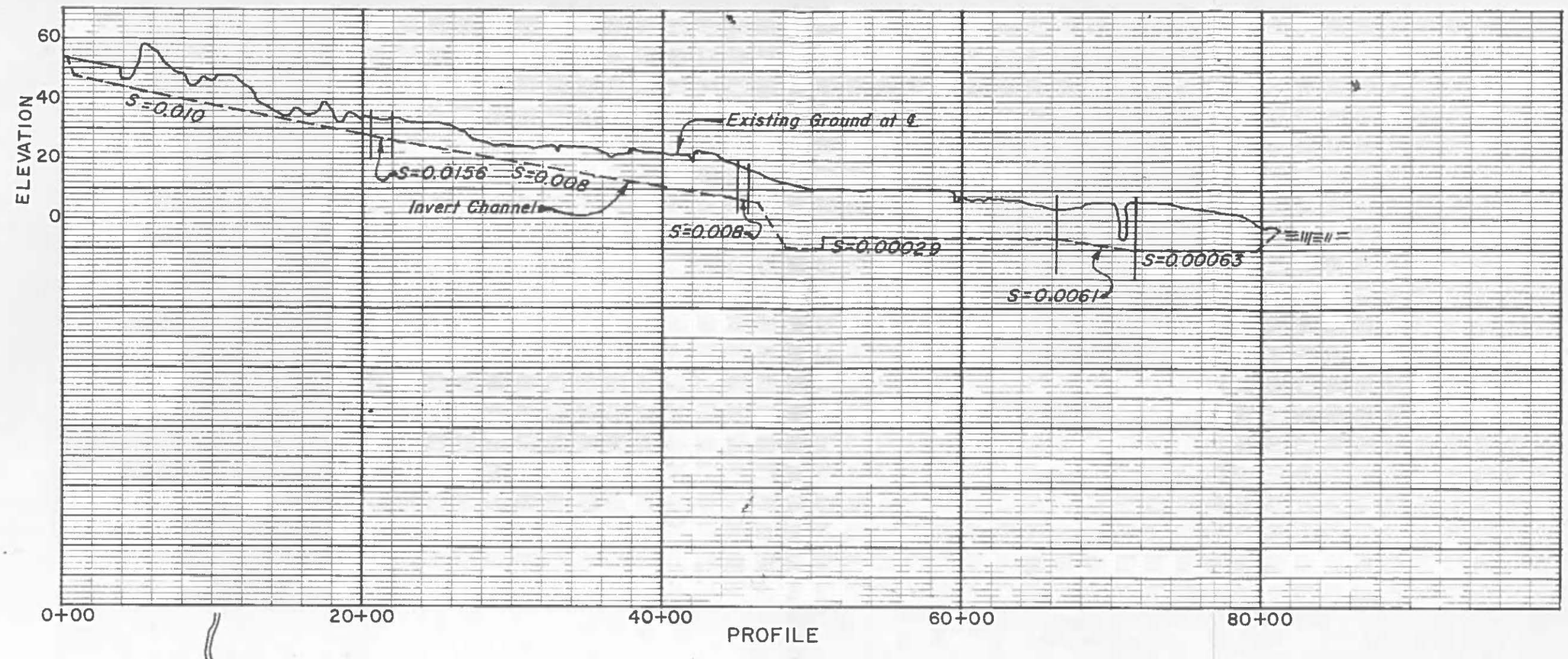


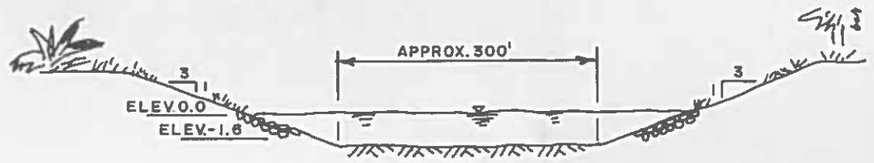
FIGURE 4
WORK PLAN

AHUIMANU CHANNEL A-1 MULTI-PURPOSE CHANNEL SYSTEM KA-1

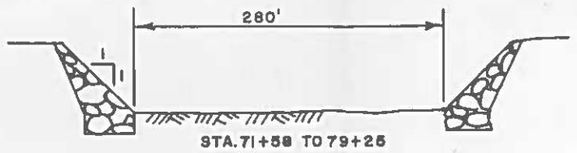
KAHALUU WATERSHED
ISLAND OF OAHU HAWAII

PRELIMINARY PLANS

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE
Prepared by S.L.W. Date 2-68 Drwg. No. 7-N-21301-4

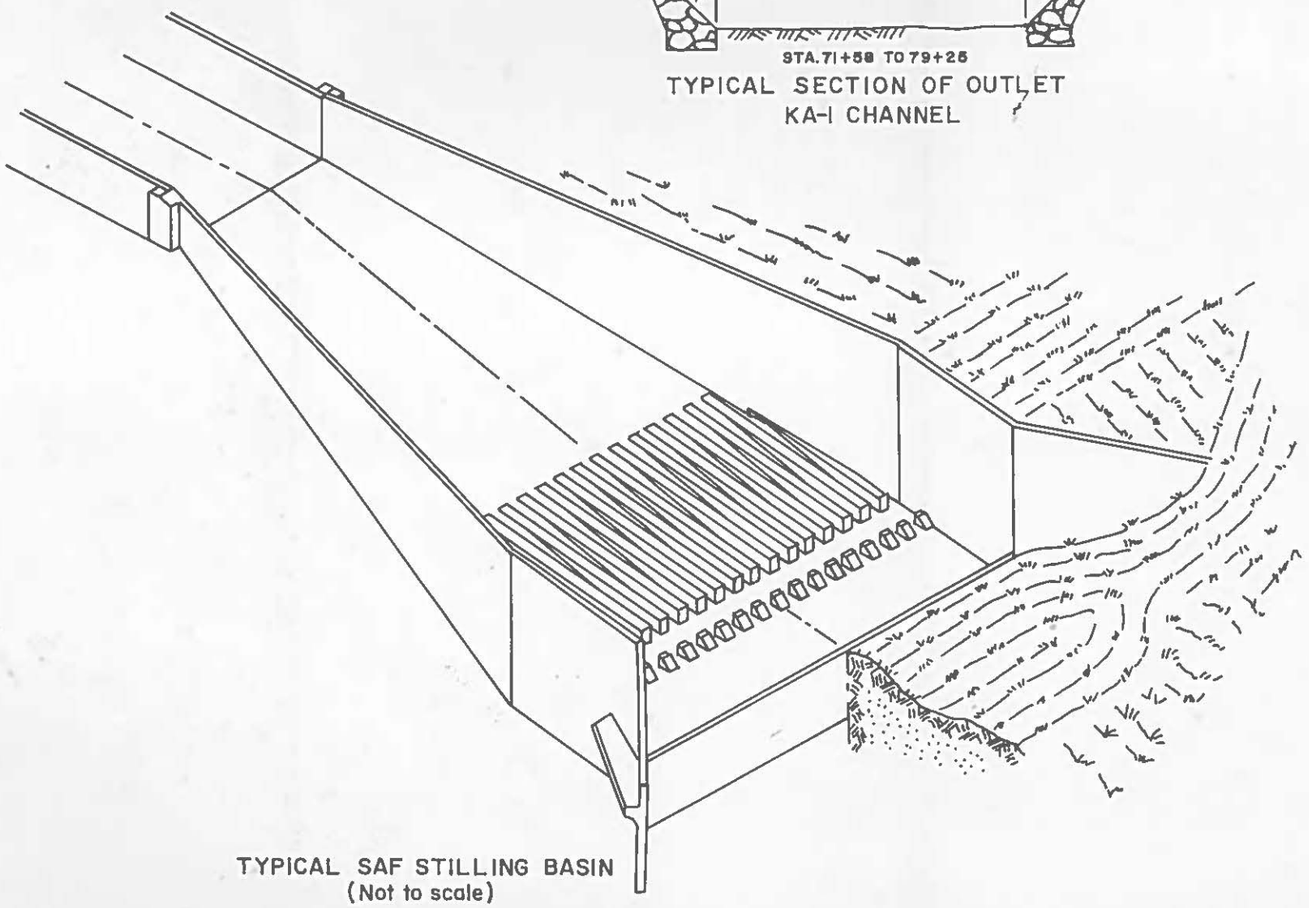


TYPICAL CROSS SECTION
OF KA-I LAGOON

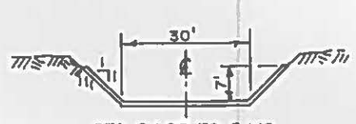


STA. 71+58 TO 79+25

TYPICAL SECTION OF OUTLET
KA-I CHANNEL

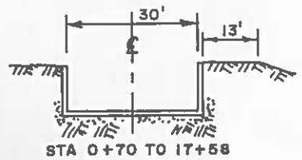


TYPICAL SAF STILLING BASIN
(Not to scale)



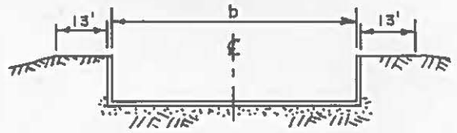
STA 0+00 TO 0+10

TYPICAL CROSS SECTION
A-I CHANNEL
(Existing)



STA 0+70 TO 17+58

VIEWS LOOKING UPSTREAM



b = 40' STA. 22+86 TO 45+09
b = 65 STA. 45+09 TO 46+45

TYPICAL CROSS SECTIONS
A-I CHANNEL

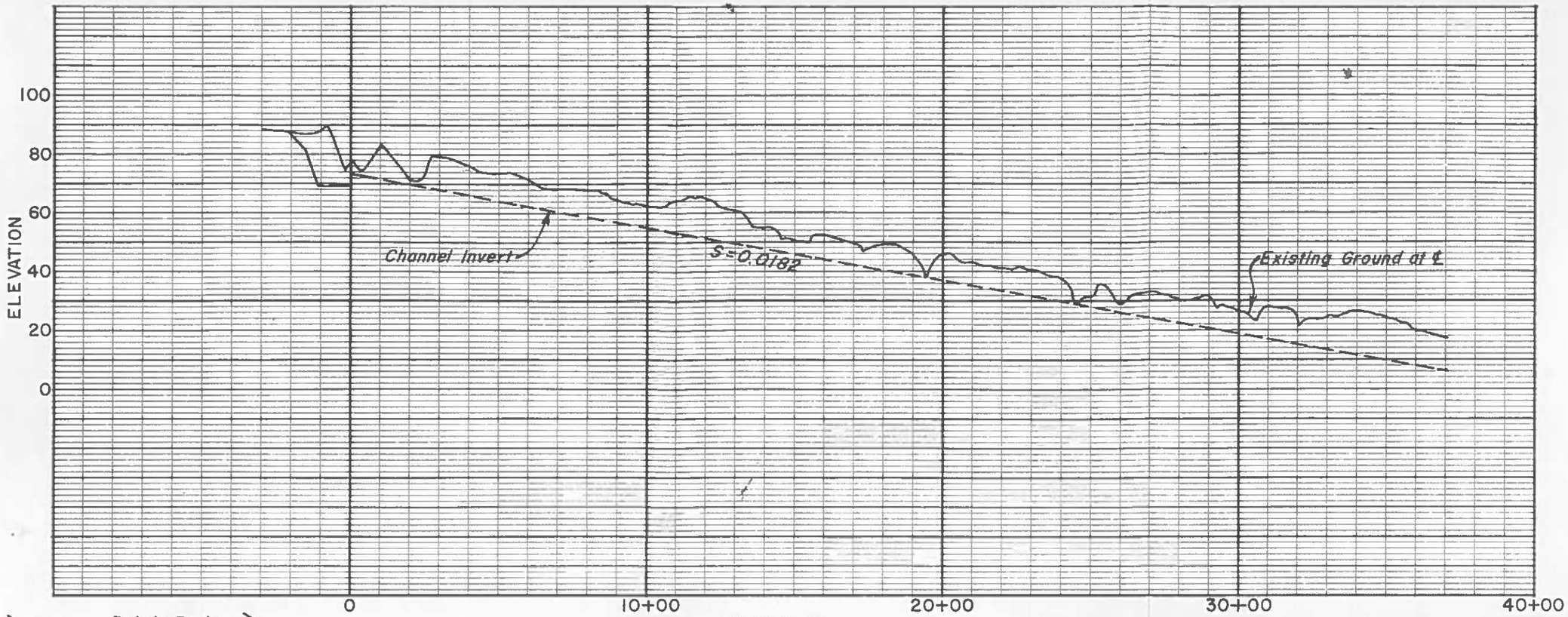
FIGURE 5
WORK PLAN

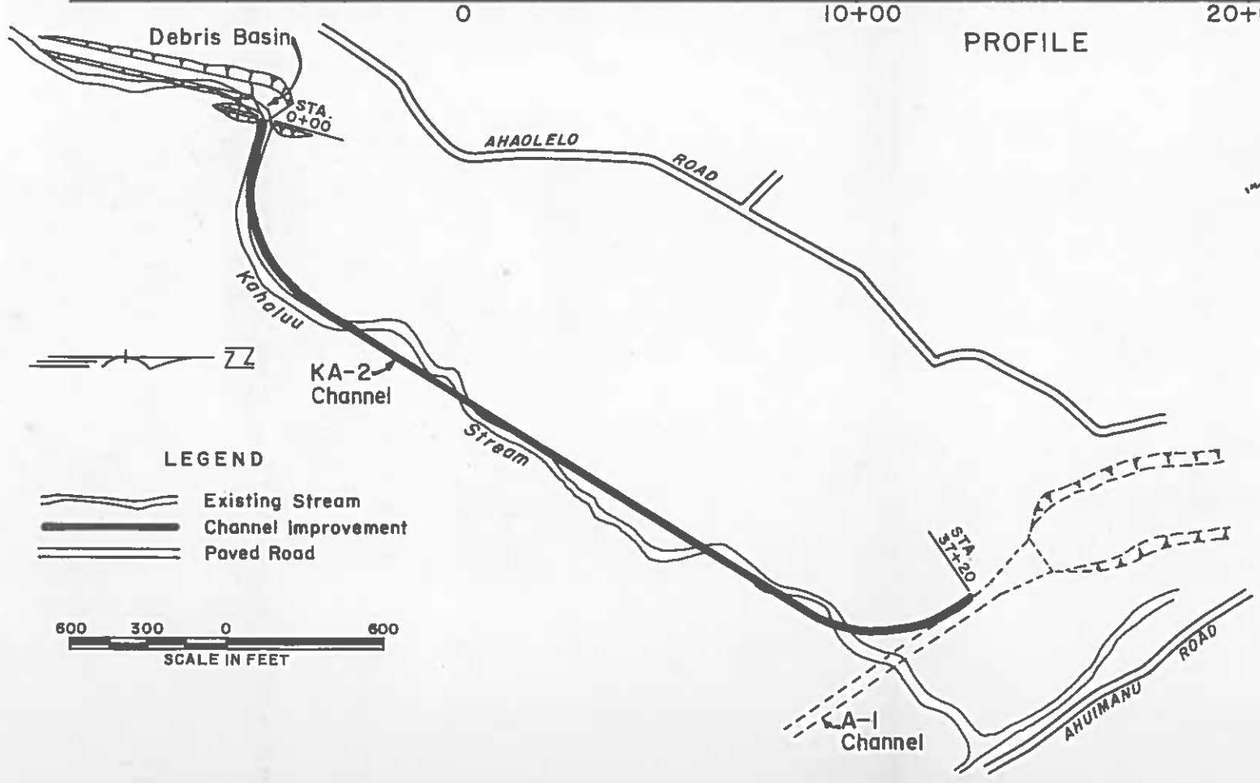
A-I AND KA-I TYPICAL CROSS SECTIONS AND STILLING BASIN

KAHALUU WATERSHED
ISLAND OF OAHU, HAWAII

PRELIMINARY PLANS

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE
Prepared by S.L.W. Date 6-68 Drwg. No 7-N-21301-5





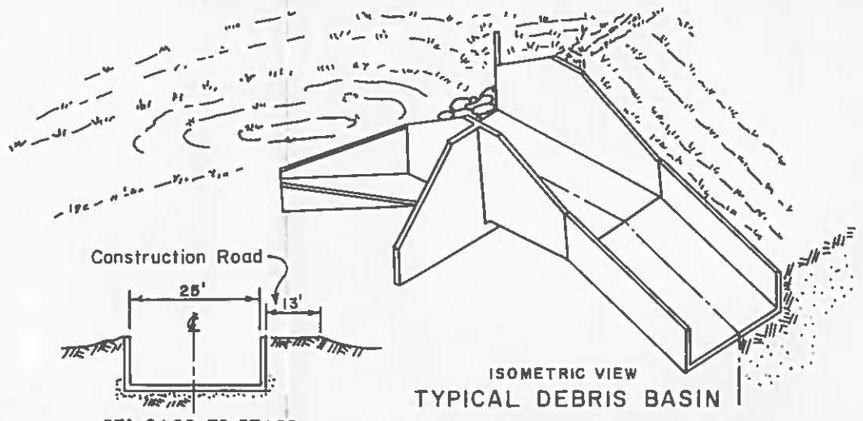


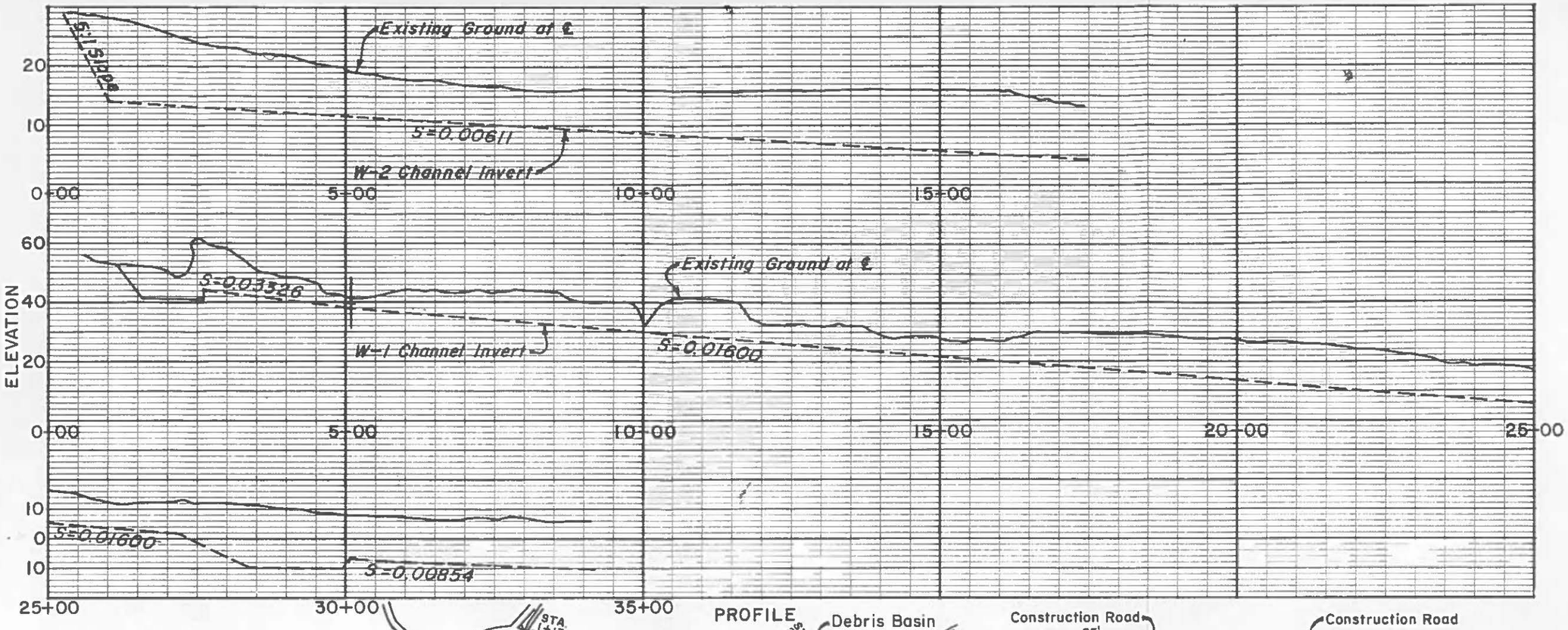
FIGURE 6
WORK PLAN

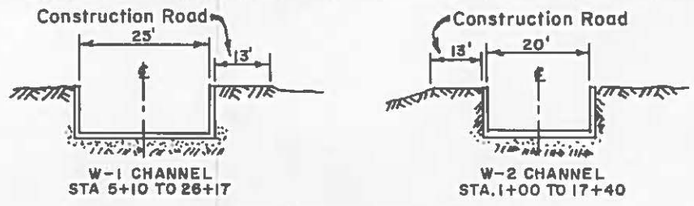
KAHALUU CHANNEL KA-2

KAHALUU WATERSHED
ISLAND OF OAHU, HAWAII

PRELIMINARY PLANS

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE
Prepared by S.L.W. Date 2-68 Drwg. No. 7-N-21301-6





VIEWS LOOKING UPSTREAM

TYPICAL CROSS SECTIONS

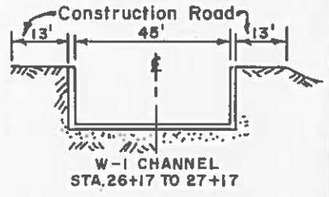
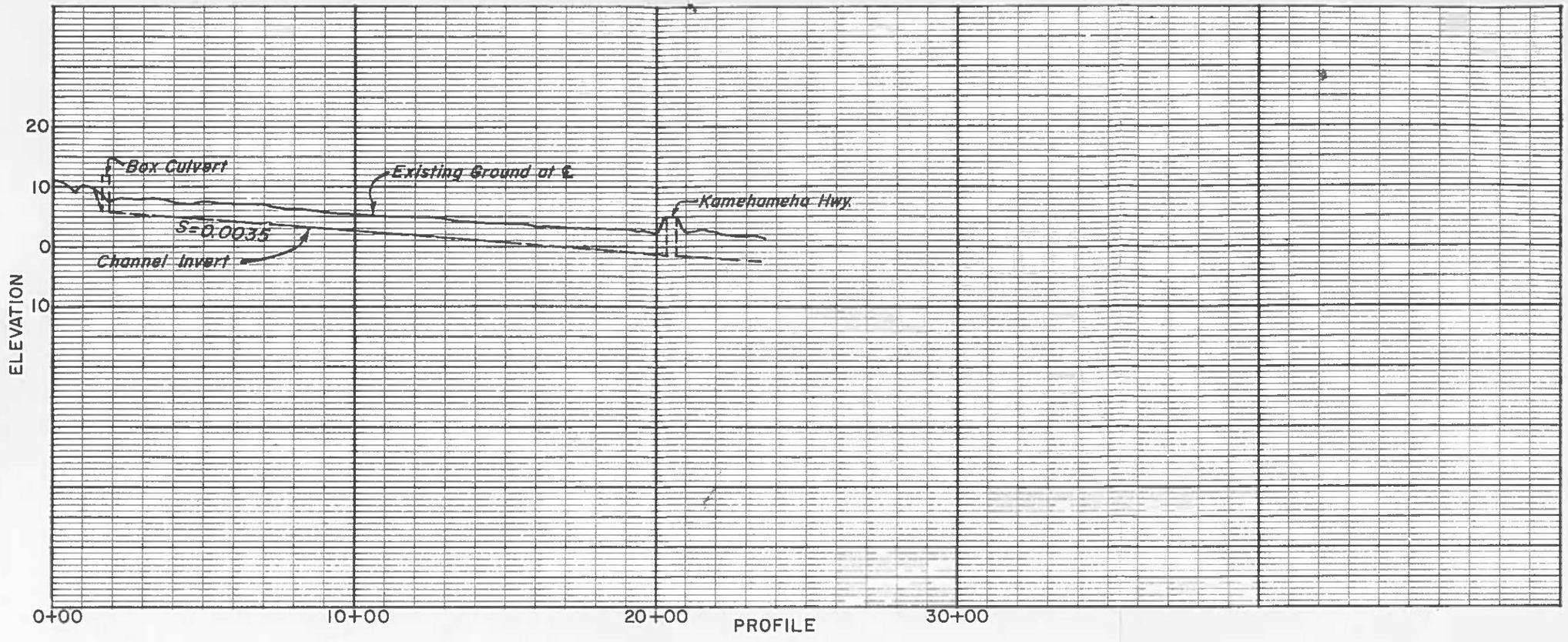


FIGURE 7
WORK PLAN

WAIHEE CHANNELS W-1 AND W-2
KAHALUU WATERSHED
ISLAND OF OAHU, HAWAII

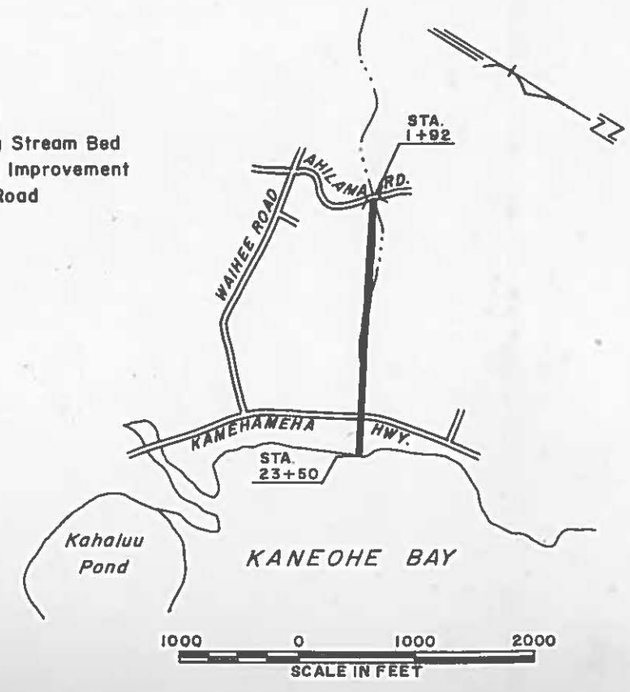
PRELIMINARY PLANS

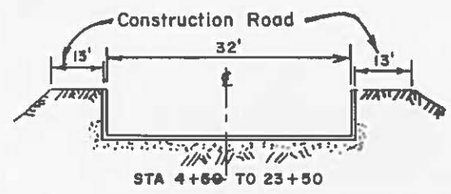
U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE
Prepared by S.L.W. Date 1-68 Drwg. No. 7-N-21301-7



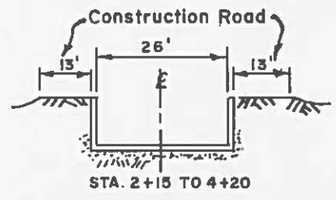
LEGEND

- Existing Stream Bed
- Channel Improvement
- Paved Road





VIEWS LOOKING UPSTREAM



TYPICAL CROSS SECTIONS

FIGURE 8
WORK PLAN

NORTH WAIHEE CHANNEL-NW

KAHALUU WATERSHED
ISLAND OF OAHU, HAWAII

PRELIMINARY PLANS

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE
Prepared by S.L.W. Date 1-68 Drwg. No. 7-N-21301-8